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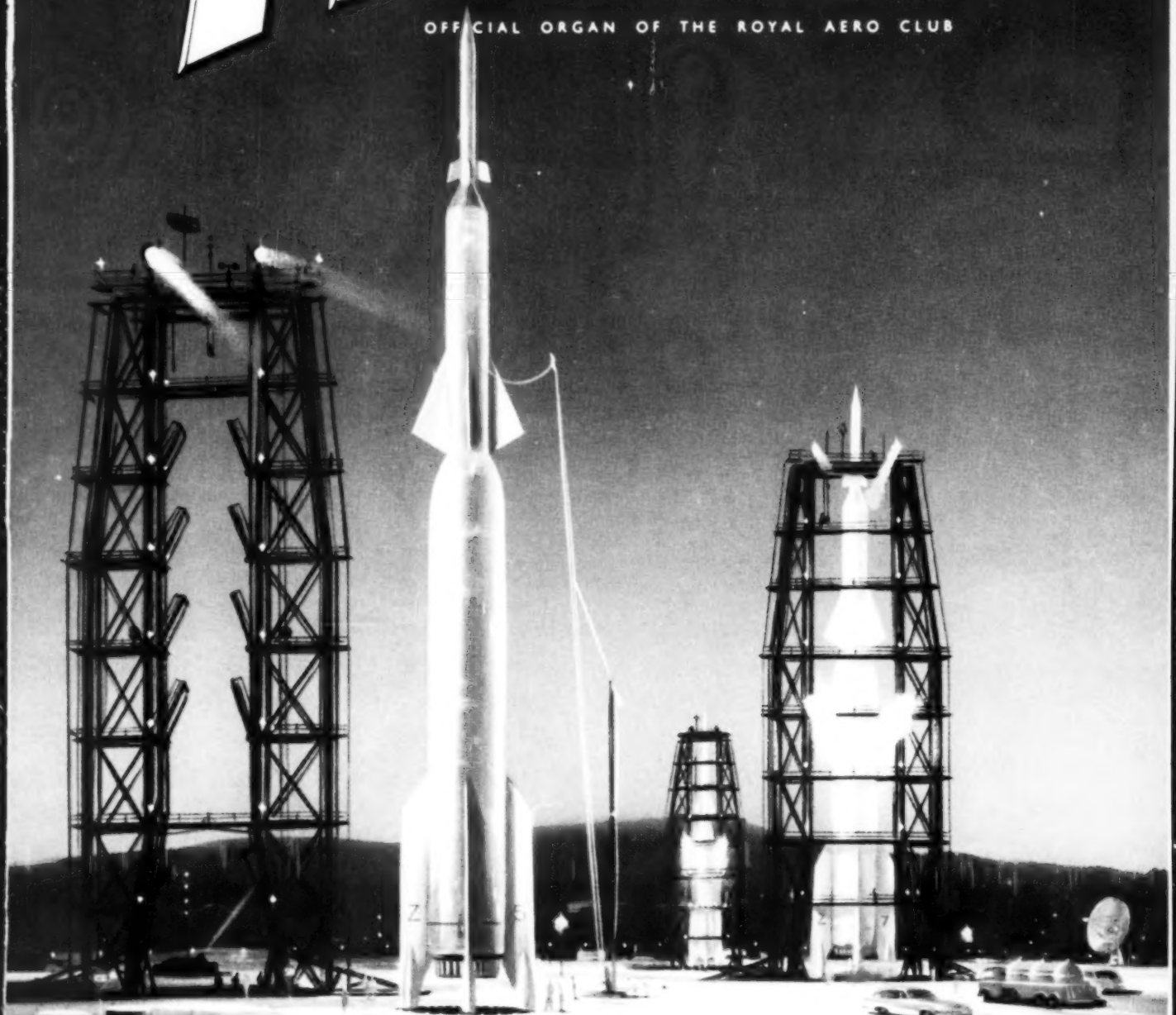

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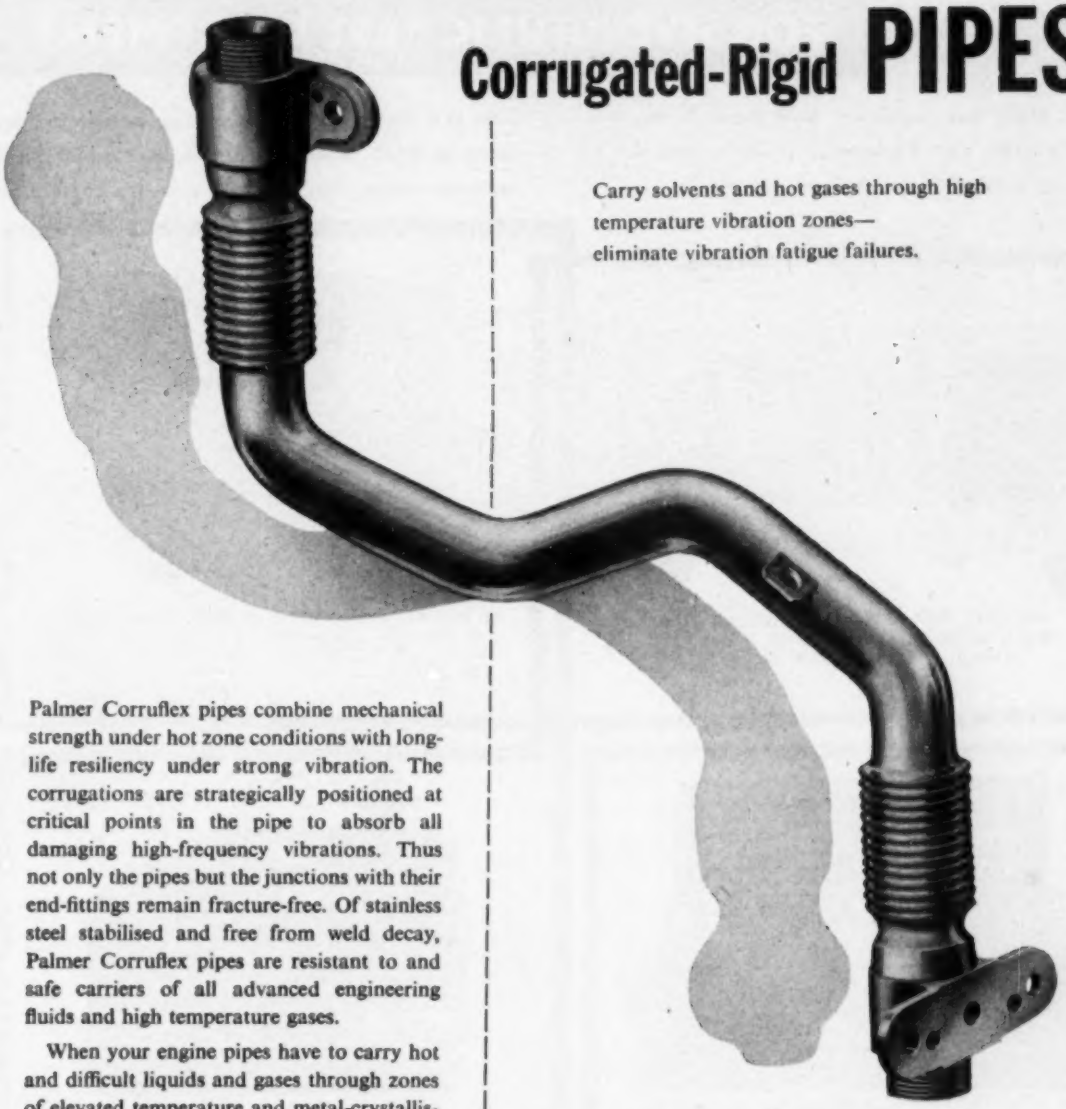

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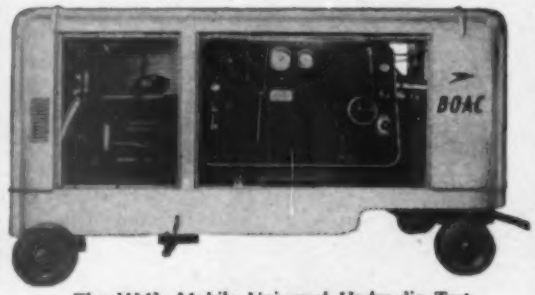

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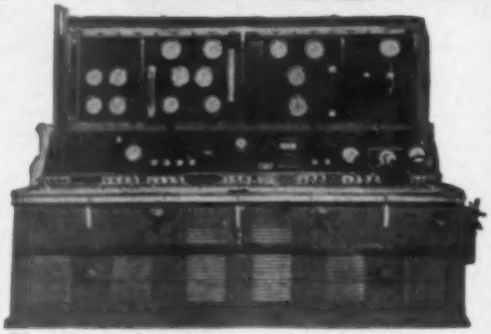

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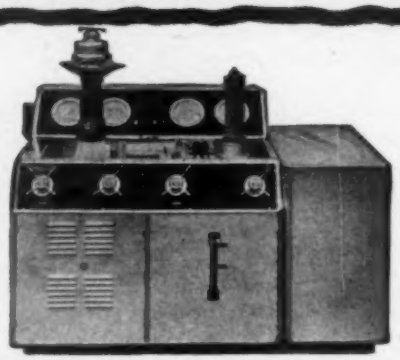

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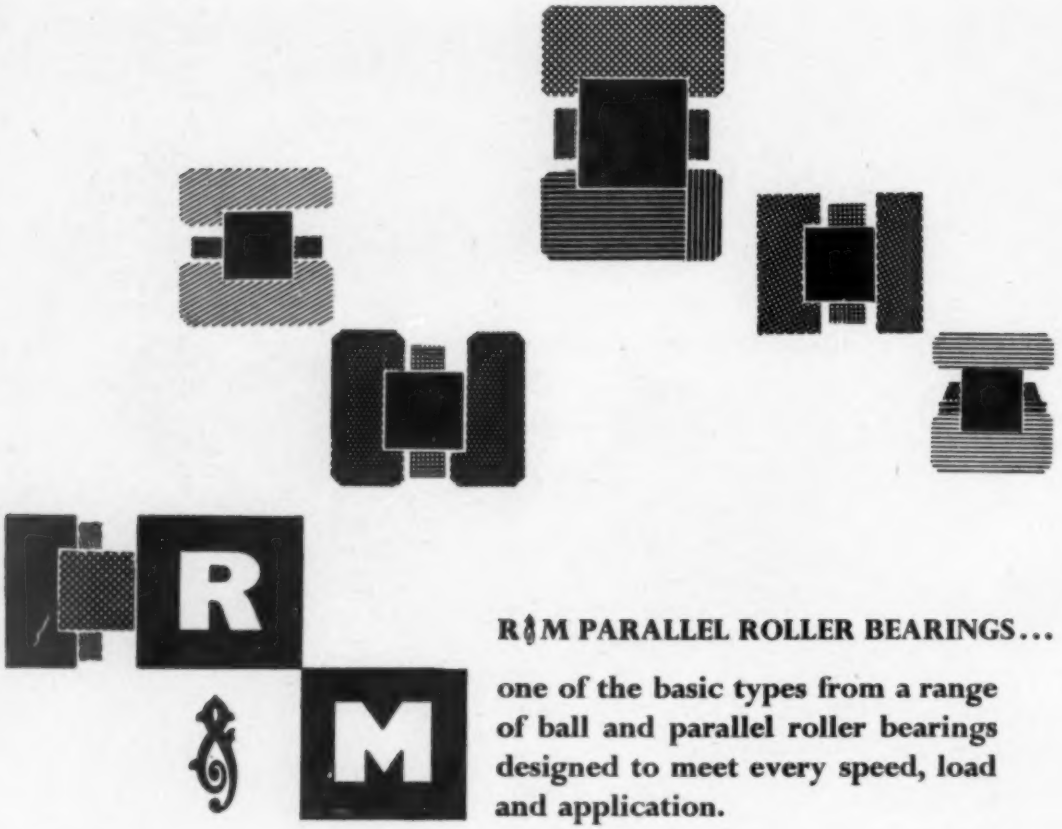

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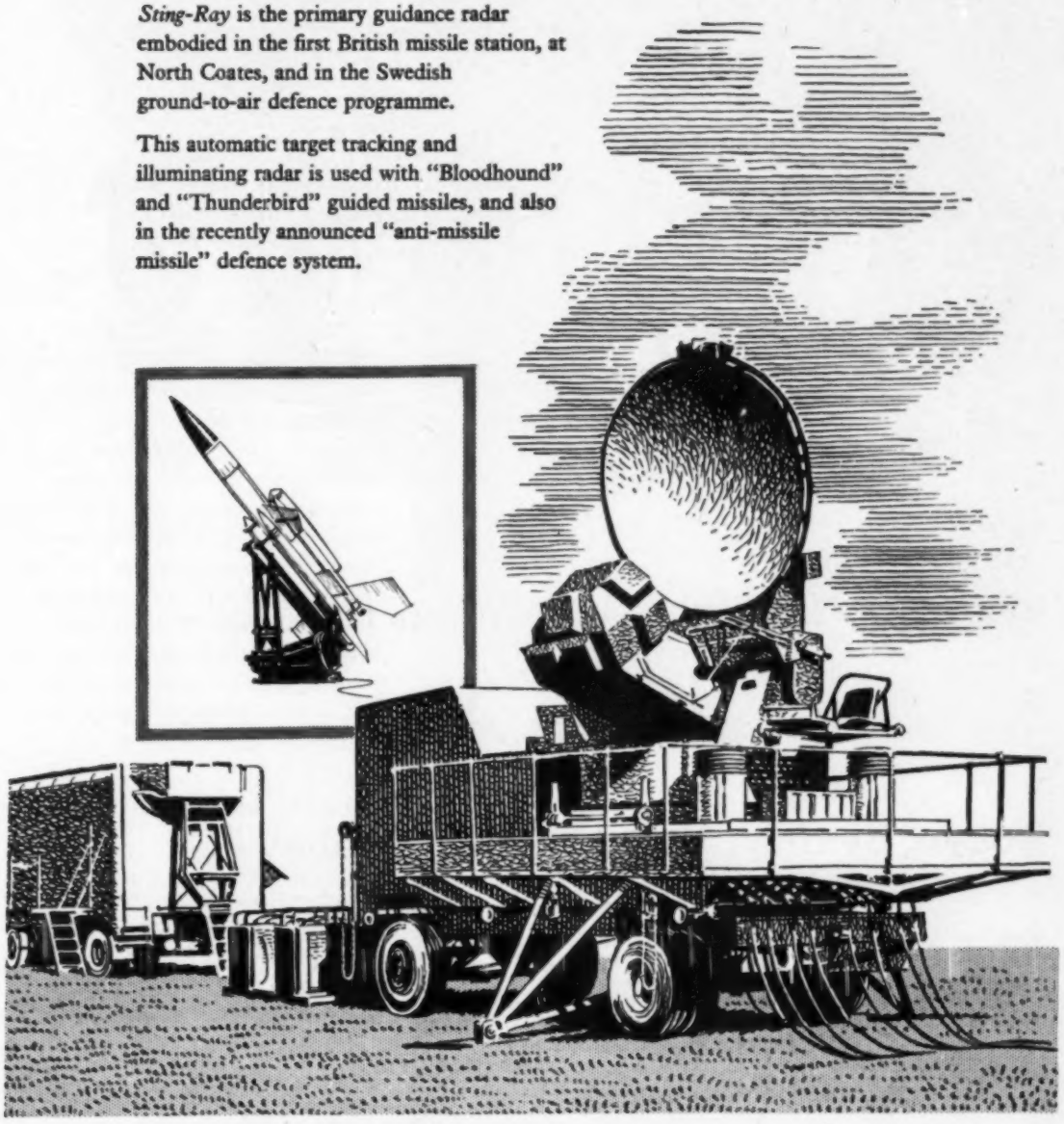

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193

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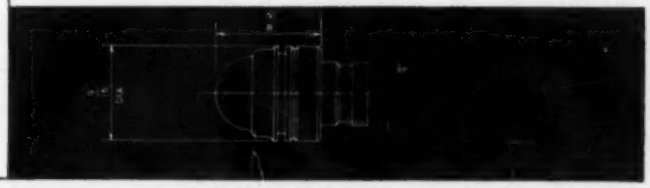

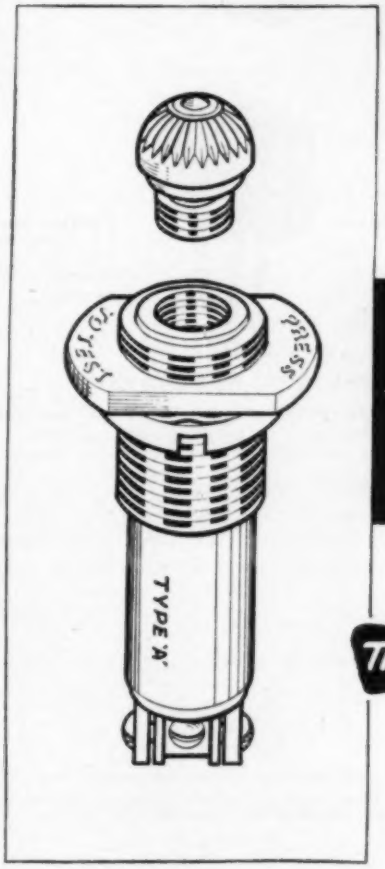

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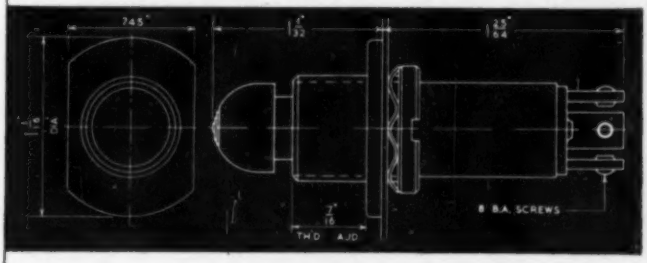

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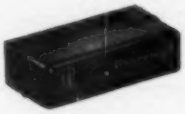

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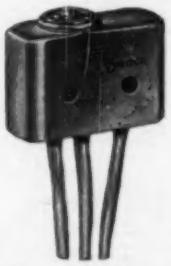

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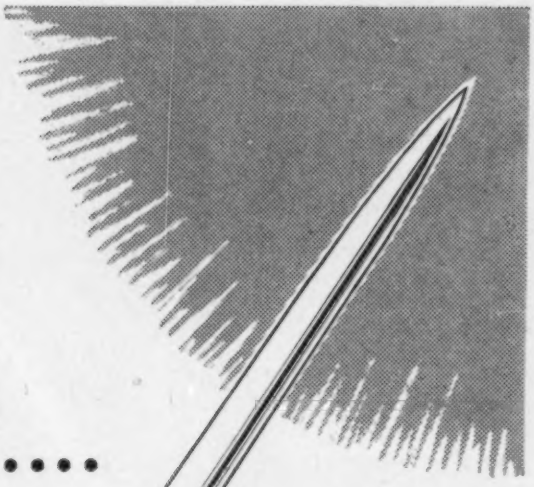

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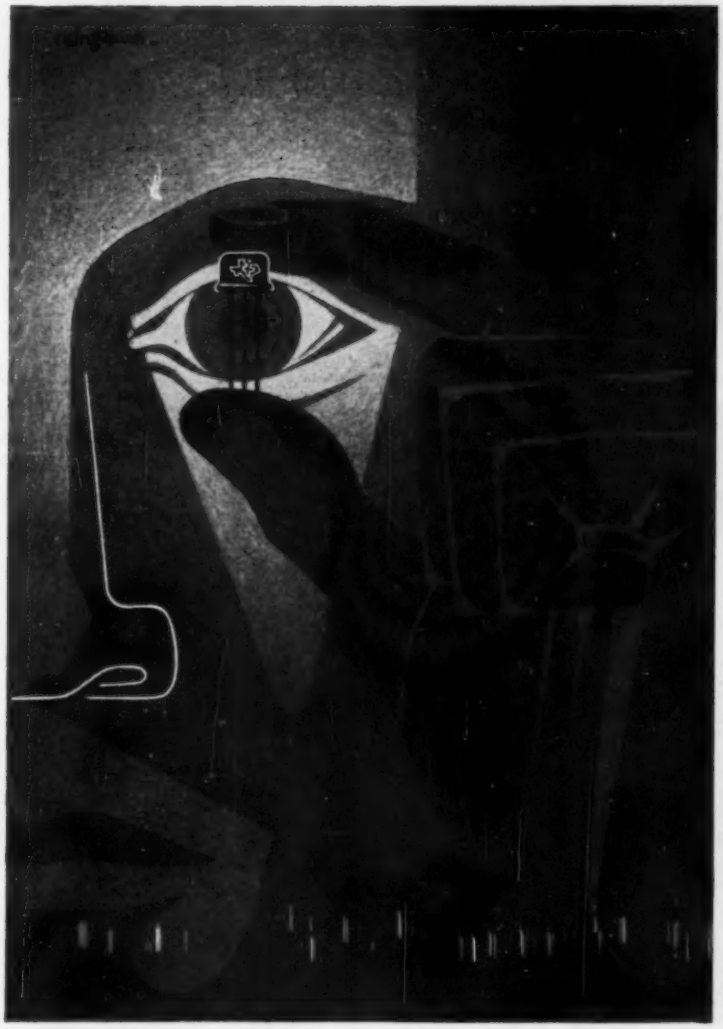

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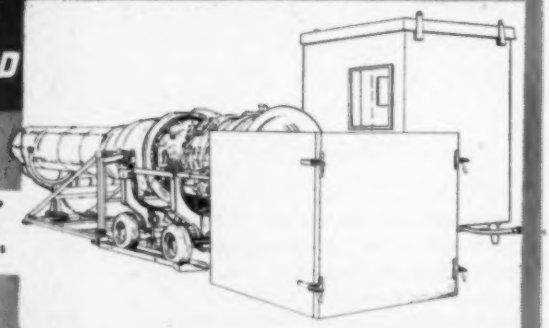
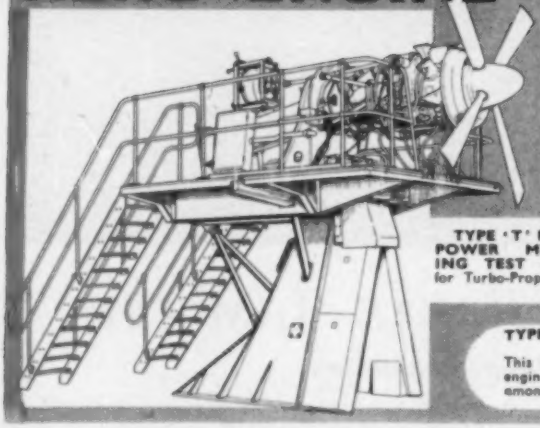


ENGINE RUN-UP STAND for Defect Checking Turbo-Jet Aero-Engines



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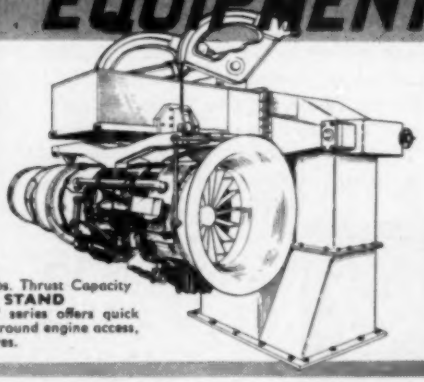

TYPE 'J' Mk. IC. 20,000 lbs. Thrust Capacity **TURBO-JET TEST STAND**
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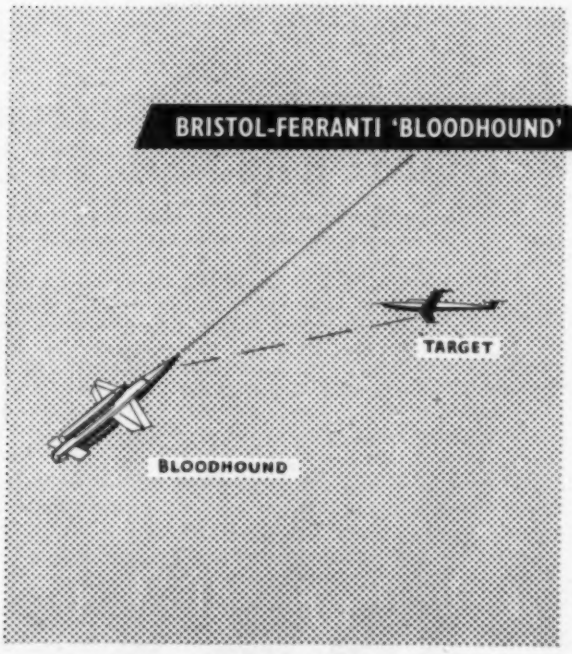

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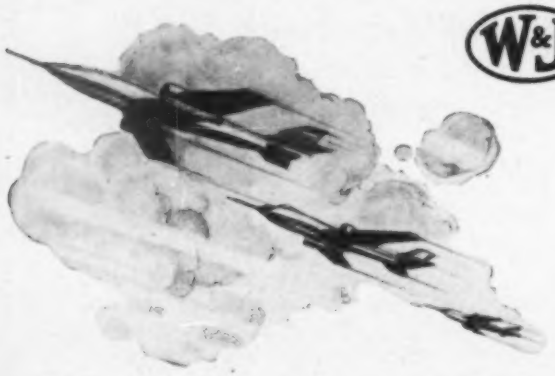

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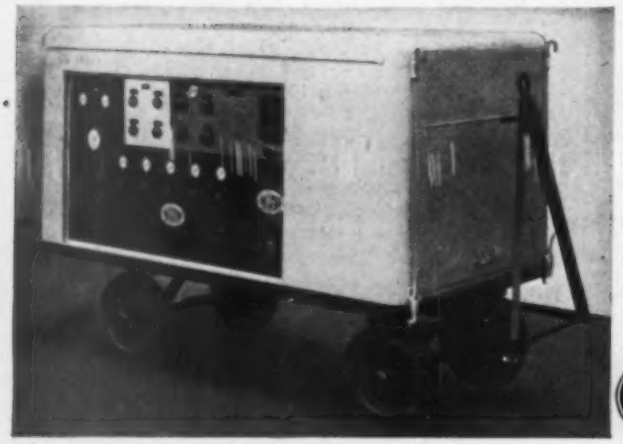

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Jet hovering under automatic control

The start of free flight trials by the Short SC.1 VTOL* jet Research Aircraft makes a significant advance towards the time when runways will be obsolescent.

Shorts are now at grips with the problem of taking off and landing vertically by use of downward-pointing jet engines. A particular cause for satisfaction in the early trials has been the faultless performance of the autostabiliser, giving automatically controlled stability during hovering before the forward wing-borne stage is reached. This embodies an automatic system of 3-axis gyro controls (triplicated for safety) using some of the air from the main supporting jet engines fed to control nozzles in wing tips, tail and nose. This unique autostabiliser control system has been developed in the experimental shops and laboratories at Shorts in Belfast—as indeed was the aircraft itself and the special gantry used for preliminary hovering. The development continues . . .

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AT Shorts

IDEAS

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The Seaslug is the Royal Navy's first ship-to-air missile. Launched from the pitching, tossing deck of its trial ship, H.M.S. Girdle Ness, it has proved its accuracy under the most trying conditions. Although the Seaslug does not need to score a hit to destroy its target, the test vehicle, without a warhead, has made direct strikes frequently on target aircraft. With long range radar, it can engage bombers up to the maximum height at which modern aircraft can fly. The firing crew is far smaller than the crew of a gun turret in a major warship.

Powered by a solid fuel sustainer motor and four boosts, the Seaslug has been designed and constructed by AWA in conjunction with the Sperry Gyroscope Co. Ltd., and G.E.C. Ltd.

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FIRST AERONAUTICAL WEEKLY IN THE WORLD FOUNDED 1909

FLIGHT and AIRCRAFT ENGINEER No 2602 Vol 74 FRIDAY 5 DECEMBER 1958

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Thoughts of Spring

THE private pilot tends to withdraw during the winter months to the club-house, to gaze moodily into the dark and fog over the top of a tankard. Although his flying may be severely curtailed, the bills keep coming in. Winter provides more time and more opportunities (after-dinner speeches, letters to the Editor) for lament, and the private flyer becomes accustomed to thinking of himself as one of a dying race—the victim of a formal and blind official machine which hates his amateur enthusiasms and would gladly see his kind fade away.

Even the summer which preceded these winter months has been fraught with difficulties—abominable weather and the apparent weight of more official oppression. The airways seem to be spreading like pre-war ribbon development.

As the froth fades from his tankard our pilot's mood grows blacker. Others who come in to thaw the frost out of limbs chilled from sitting in a 20-year-old open cockpit add to the gloom. The prospects brighten only when everyone has stuck his pin in the effigy of the Minister.

The coming closure of Croydon may be regarded by many as the severest blow ever to British private flying, even though equally unkind cuts may be expected to follow in other parts of the country. But we honestly wonder whether the struggle for Croydon does not, in fact, mark an important change for the better in the fortunes of private flying. Croydon will surely close; but there will remain a solid and respected grouping of private-flying organizations which have now been included in a Government committee specifically formed to look after their interests. In exchange for Croydon we have some official sympathy and a reasonable promise of future assistance. Surely this is the greatest advance yet?

Already the terms of tenure at Biggin Hill, which was offered as the official alternative base for the private operators from Croydon, have been materially improved. The Government is looking into the question of providing a "Croydon replacement" to be available as something of a private flyers' London Airport, and there is some prospect of Gatwick being made available for certain types of non-commercial flying. The door of official support almost crashed shut—but not quite—and the opening should now be carefully and sensibly exploited.

Another lament frequently heard is that no good new private aircraft can be had in England at the right price, and that those now in use are woefully old. But for several years the Popular Flying Association has been actively encouraging and assisting in the introduction, official approval and private construction of several useful types, and in this the A.R.B. has been particularly helpful, whatever evidence to the contrary may have been adduced in isolated cases. A number of Turbulents and Turbis are taking shape and some have already flown.

This is not all. At least three companies are producing or preparing new light aircraft suitable for club use. More and more bright little Turbulents are coming from the Croydon workshops of Rollason Aircraft and Engines. The same company has the import and sales rights for the Normande Jodel D.117 and the new Mousquetaire four-seater, and can offer delivery at a reasonable price with a British C. of A. Volkswagen, Porsche and Flying Neptune engines are available and other types may be found. Garland-Bianchi are launching the Linnet and a French-built Emeraude; the Thruxton Jackaroo and converted Chipmunk and Prentice have now been on the market for some time; Phoenix offer the Luton Minor and Major.

As for bases, there must be at least a dozen small privately owned fields scattered about this country where aircraft regularly operate, but concerning which little information is given in official listings. Even in respect of equipment there has been notable progress, and two types of completely portable radio direction-finders can be bought at a fraction of the cost of the full-scale equipment.

Far from feeling despondent about British private and club flying, we look forward to next spring with something very close to optimism. A year from now we may look back on the end of Croydon and the beginning of the new private-flying era.

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FROM ALL QUARTERS

The Industry: Commons Questions

IN the House of Commons last Monday the Minister of Supply, Mr. Aubrey Jones, replied "no" to a question asking whether he would appoint a select committee to enquire into the present state of the aircraft industry. It had been asked by Mr. Maurice Edelman (Lab., Coventry N.), and later a party of Labour members, led by Mr. Frank Beswick, tabled a motion making a similar request.

On Monday, also, the Minister answered questions about Government assistance in VTOL projects. Asked if there was any prospect of a joint project with the U.S.A., Mr. Aubrey Jones said it was possible that "some arrangement might be reached, but comment would be premature."

The Prime Minister on Prestwick

ANSWERING Parliamentary questions last week about Scottish Aviation, Ltd., the Prime Minister said he had received letters from Ayrshire local authorities about the possibilities of encouraging further orders for the Twin Pioneer. In his reply he had pointed out that financial assistance had been given in the development of these aircraft, that 32 of them had been ordered for the R.A.F. and that four more were now to be ordered. The Government would continue to assist the company in its efforts to sell the aircraft overseas.

When Mr. Emrys Hughes (Lab., South Ayrshire) went on to ask whether the Prime Minister was aware that local authorities were gravely concerned because insufficient attention was being devoted to the problem of providing alternative work for this industry, and that orders for the R.A.F. were not likely to solve it, Mr. Macmillan replied: "We are in close touch with the company and will do everything we can to help, but at present I think it is in the overseas market that the best hope lies for further orders for this aircraft."

Towards the £150m

EXPORTS by the British aircraft industry for the first ten months of this year have exceeded by 9 per cent the previous annual record achieved in 1957. The total, £126,883,826, represents an annual figure of over £150m and is 45 per cent more than the total achieved during the first ten months of last year.

In the January-October period the sale of aircraft and parts amounted to £81,365,230; engines to £40,532,824; electrical equipment to £2,845,975; and instruments to £1,667,344. India was the leading overseas customer, buying aircraft and parts worth £15,514,467; next came Canada (£13,471,828) and the U.S.A. (£11,197,756).

The October exports figure, £10,576,205, was £1½m higher than the total for October last year and exceeded the September 1958 figure by over £600,000.

Russian Nuclear Bomber

WIDE publicity has been given to a report in the December 1 issue of the American journal *Aviation Week*, describing a nuclear-powered bomber which is said to have been flying in the Soviet Union for two months. The aircraft is stated to have a span of 78ft and a length of 195ft and to be powered with two conventional turbojets and two 70,000 lb-thrust nuclear (direct cycle) turbojets. U.S. Defense Secretary Neil McElroy is "highly sceptical."

Seaslug Trials' Success

WHEN the guided-weapons trials ship H.M.S. *Girdle Ness* returned to Devonport on November 26 after seven months' firing trials in the Mediterranean her commanding officer, Capt. M. G. Greig, said that Seaslug was extremely accurate and "the best thing the Navy has ever had." Since he took command in July 1956 the ship had fired nearly 100 missiles and made extensive trials of every part of the system; both missile and equipment had stood up to the searching test extremely well. "We have had our troubles and still have a few," said Capt. Greig, "but we know that the system is thoroughly sound and most effective and will do all and more than was expected of it." [A feature article on the A.W.A. Seaslug and H.M.S. *Girdle Ness* was published in *Flight* for November 21, pp. 790-4.]

Mr. Onassis and the Comet

OLYMPIC AIRWAYS' interest in the Comet 4 was in the news last Monday when de Havilland flew the airline's founder, Mr. Aristotle Onassis, from Nice to London in G-APDH. A strong team of D.H. sales and engineering executives was on board.

Tynes for the Rotodyne

FOLLOWING last week's report about financing of the Rotodyne comes a further newspaper report that the Government will advance £4m, to be shared between Fairey and Rolls-Royce. The Tyne engine (it is confirmed by Fairey) is being considered for the Rotodyne; but Fairey and Government spokesmen are unable to confirm any decision about finance.

All-the-way Atlas

CULMINATING five years of work, the U.S. Air Force Atlas inter-continental ballistic missile was successfully flown over its entire 6,325-mile design range on November 28. As forecast in our description of the missile on p. 874, the nose-cone used was not the blunt G.E. Mk 1 but a pointed model apparently intended to ablate (burn off in layers).

The Week's Good Show

A GANNET engaged in Double Mamba development flying and piloted by Harry Rayner of Armstrong Siddeley recently suffered nosewheel failure (the assembly jammed half-down). Tom Frost took off in a Jet Provost for a close look and decided to try and bump the wheel down with the Provost's canopy. At the twelfth try he succeeded in nudging the wheel—which, however, remained fast. Rayner then tried bumping the wheel on the runway, although the Gannet had oversize propellers. Again, no success. So the runway was sprayed with foam and Rayner put the Gannet down on its belly. The nosewheel thereupon retracted and the Gannet came to rest.

L. Massey Hilton

WE record with regret that Mr. Louis Massey Hilton, D.F.C., A.F.C., A.F.R.Ae.S., a director of the Fairey Aviation Co., Ltd., from 1934 until his retirement on medical advice in January this year, died last Friday (November 28) at the age of 59.

He joined the company in 1931 from the R.A.F., in which he was a flight lieutenant, and although only 32 he had already 14 years' flying experience behind him. This included operations with the North Russian Relief Force in 1919, for which he was awarded the D.F.C., and experimental work on aircraft carriers (including deck-landings in the Fairey Fox), for which he was awarded the A.F.C. When Sir Richard Fairey was looking for a young man with experience in Naval aviation, Maj. Maurice Wright (who had been an Air Ministry test pilot until he joined Fairey's in 1925) remembered Massey Hilton as a young R.A.F. officer who had served with him in earlier years at the Marine Aircraft Experimental Establishment at Felixstowe: so Massey Hilton resigned from the R.A.F. to join Fairey, being appointed a director three years later (in 1934).

Mr. Massey Hilton

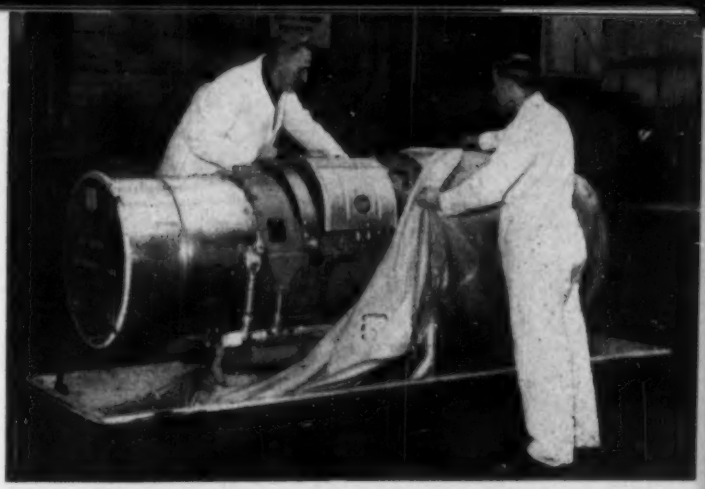
As technical director (1939-41) he was responsible for adapting two different Naval specifications so that eventually one machine, the Firefly, met both requirements. At the end of the war he was largely responsible for the formation of Fairey's Australian and Canadian subsidiaries and in 1951 he was made assistant managing director. Ill-health, however, dogged him and he was compelled to relinquish this appointment in 1956 and to retire from the Board in January this year—his resignation being accepted by the company "with the greatest regret."

Hawker Siddeley Results

ALTHOUGH the gross trading profit for the Hawker Siddeley Group—disclosed in a preliminary financial statement last week—rose in the year ended July 31, from £20m to £24m the net profit fell from £8m to £7m, and after allowing for amounts due to minority shareholders this was reduced further from £7m to £5m. The fall was mainly due to increased charges for depreciation (£6.3m to £8.4m) and special development (£1.6m to £2.9m).

Despite this reduction in available profits, the dividend rate was maintained at 10 per cent, leaving retained profits at £3.5m as compared with £5.5m in 1956-57.

Trading profit on the Group's British interests was unchanged at £12m. But the Canadian interests showed a rapid increase,



***OVERCOAT FOR ORPHEUS:** A Bristol Orpheus turbojet, destined for a Lockheed Jetstar, standing in the base of its packing case and having its dust-and-damp-proof zip-fastened plastic envelope put on prior to shipment to Marietta, Georgia*

their profits rising from £8m to a figure equal to that shown by the British companies. Although the Home concerns were burdened with higher development and taxation charges than their Canadian associates, the huge amounts charged by the latter against depreciation and minority shareholders meant that the British companies continued to contribute almost two-thirds of the Group's net profit.

AGARD General Assembly

WHEN the Advisory Group for Aeronautical Research and Development (AGARD) held its eighth general assembly in Denmark recently, the chairman of the Standing Group of NATO, Admiral Sir M. M. Denny, emphasized that as a NATO agency AGARD had provided invaluable assistance in bringing together leading NATO experts in the aeronautical field. Among other speakers were Maj-Gen. B. A. Schriever, head of the U.S.A.F. Ballistic Missiles Division; Dr. Norman F. Ramsay, speaking on behalf of the Secretary-General of NATO; and Gen. Leon W. Johnson, representing the Supreme Allied Commander in Europe. A round-table discussion on *The Impact of Space Technology on Research and Development* dealt with the human factor in space flight as well as the problems of outer space physics, the guidance of satellites, propulsion, structures and materials.

Appointed works manager of A. V. Roe and Co., Ltd., is Mr. Harry Dobson. He joined the company as an apprentice in 1939 and in 1946 was put in charge of the ancillary department. After occupying a succession of increasingly responsible posts, he was appointed assistant works manager in 1955. Mr. Dobson, who is 35 years of age, is the son of Sir Roy Dobson, managing director of the Hawker Siddeley Group

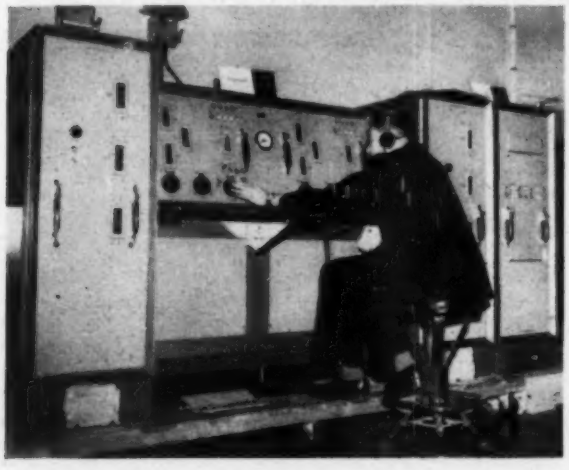
Scimitar Inquest

AT last Monday's inquest on Cdr. J. D. Russell, R.N., who lost his life when his Scimitar went overboard while landing on H.M.S. *Victorious* on September 25, a verdict of accidental death was returned. Evidence was given on various difficulties which the pilot encountered in trying to escape; and an Admiralty spokesman, in London after the inquest, disclosed facts about arrester-wire trouble. Details of the evidence and the Admiralty statement will be given in these pages next week.

Versatile Radar Simulator

A RADAR simulator of remarkable versatility has been completed by a British firm and is to be delivered to the Italian Army this month. Costing £125,000, it is a product of Radar Simulators, Ltd., a company of the Solartron Electronic Group.

This particular simulator caters for 14 aircraft targets and has control positions for two pupils under training for using surveillance radar with a 60-mile range; but other versions of the same Solartron equipment can simulate any type of ground, air and marine radar, and a much larger number of targets can be provided. Alternatively, surface exercises with ships or submarines, using radar or asdic, can be presented. The equipment may be used for research and development as well as for training.



The Solartron system reproduces the aerial characteristics of the actual transmitters and "target" behaviour may be programmed instead of being directly controlled by a human operator. Built on the modular principle, the simulator can be expanded with additional or new units.

An important feature is that targets and other "participants" are simulated by electro-mechanical analogues which, supplied with the limiting performance parameters of an aircraft or other vehicle, feed actual radar or asdic returns into a main system that is, in effect, a closed-circuit radar. The resulting picture can also be superimposed on a live radar presentation. For example, controllers in low-density-traffic areas could be trained for intensive operations by feeding simulated objects into the existing presentation. Similarly, additional targets or other features could be introduced into actual military exercises to present various alternative courses of action. Complete exercises can, of course, be staged without the cost and complication of using actual aircraft.

Countermeasures can also be simulated, and the system could be used for discreetly testing new measures without the necessity for actually radiating signals. Where such devices as parachuted noise-jammers are used, the drift of the jammer caused by wind can be preset in the simulator to give fully realistic behaviour.

During a demonstration at the new Solartron factory at Farnborough last week a brief exercise was shown, involving four fighters, four bombers and two "stray" aircraft, together with the effects of a parachuted noise-jammer. Several NATO countries are interested in, or already operate, Solartron simulators.

IN BRIEF

Ten Hawker Hunters reached Amman from Cyprus on November 25, forming the balance of the 12 Hunters provided for the Jordan Air Force under an agreement between Jordan and the United States, and purchased by the U.S. in Britain under the offshore procurement programme.

* * *

The R.Ae.S. main lecture by Mr. Raoul Hafner on January 8, to which Helicopter Association members have been invited, will now be called *Safety in Mechanisms* and not *The Tandem Rotor Helicopter* as previously advertised.

* * *

We regret to record that A. V-M. C. A. Stevens, C.B., C.B.E., M.C., who was S.A.S.O. at Home Command from 1951 until his retirement from the R.A.F. in 1954, died on November 30 at the age of 60. As a day bomber pilot, he led the first raid on Mannheim in 1917.

* * *

The budget committee of the West German Bundestag, last week approved in principle a DM. 2,000m (about £166m) programme for acquiring front-line aircraft for the G.A.F. It is proposed that most of these—Lockheed F-104 Starfighters and Fiat G-91s—should be licence-built in West Germany. A sum of DM. 50m (about £4m) is also envisaged for the purchase of Sud Aviation Alouettes.

* * *

At a recent meeting in London of COSPAR, the committee on space research established by the International Council of Scientific Unions, a constitution was drawn up and an executive committee was elected. Committee-members are Prof. H. C. van de Hulst, Leiden (president); Prof. E. K. Fedorov, Moscow, and Prof. W. A. Noyes Jr., New York (vice-presidents); Prof. Maurice Roy, Chatillon-sous-Bagneux; and Prof. H. S. W. Massey, London.

***NEAR REALITY:** An operator controlling two simulated aircraft and countermeasures at one of the consoles of the Solartron radar simulator described on this page*

Taking off from a field near the River Lippe in West Germany during an Army exercise last October the C.O. of No. 230 Sqn., S/L. W. J. Simpson, demonstrates the Pioneer's STOL characteristics

PIONEERING WITH THE ARMY

The Support Rôles of No. 230 Squadron

WITH the introduction into service of ever faster and higher-flying aircraft, implying continually more implicit reliance on advanced instrumentation and radio and radar aids, the days when a Royal Air Force pilot flew "by the seat of his pants" have receded into history. Nowadays he is under guidance from the moment he taxies out to when he taxies in; more often than not he scarcely sees the ground from the time of take-off until he lands, and personal basic-navigation techniques are seldom used other than in elementary-training cross-country flights.

There is a notable exception, however, to this large reliance on aids of one kind and another. The work of No. 230 Squadron, equipped with Scottish Aviation Pioneer C.C.1s (Alvis Leonides engine) and the only R.A.F. unit of its kind in the U.K., depends very greatly for its success on accurate personal navigation. For these aircraft, employed on Army support duties, operate into and out of fields; and their usefulness in this rôle depends entirely in the first instance on the pilot's ability to find his way accurately about the countryside at low levels.

No. 230 is one of the R.A.F.'s youngest squadrons but bears an old and distinguished number. It was formed, however, as No. 215 and came into existence at the beginning of May 1956 as a short-range light transport squadron. It operated under this number for two years and four months but on September 1 this year became No. 230 Sqn., thus inheriting a flying-boat ancestry, following the disbandment of the Sunderland squadron bearing tnat number at Pembroke Dock on January 31 last year. No. 230 was awarded a Standard before its demise, and this is to be presented to the squadron some time next year, probably after it has received the Twin Pioneers with which it is due to be equipped in the spring of 1959.

Since it comes under the administrative control of Transport Command, No. 230 is based at one of that Command's stations, R.A.F. Dishforth. This is also the home of No. 30 Sqn., equipped with Beverleys, and No. 242 Operational Conversion Unit (Beverleys and Hastings). The Pioneers use the airfield's grass areas for landing and take-off, and have to be extremely careful to avoid the slipstream of the larger machines. Beverleys especially, with their engines set in a high wing, are awkward neighbours for the Pioneers; and taxying or flying near the slipstream of these big aircraft can be a hazardous business for No. 230 Sqn. While the Pioneer's generous wing-area is splendid for STOL and slow-flying work (as amply demonstrated during recent years in Malaya and Aden), it can be a liability in gusty conditions. The squadron commander, S/L. W. J. Simpson, D.F.C., a forthright New Zealander who flew Mosquitoes on P.F.F. duties during the war, extols the virtues of his present mount for the tasks it has to perform but emphasizes that it needs careful handling.

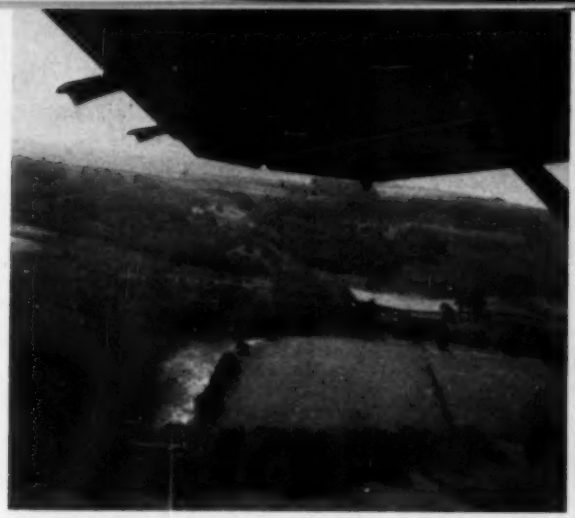
Though administratively coming under the ægis of R.A.F. Transport Command, No. 230 Sqn. is subject to the Army's operational control. Its job is to assist formations employed in the internal security rôle, which are prepared to move quickly to anywhere in the world where trouble may arise. The squadron was until recently associated with No. 24 Brigade, based at Barnard Castle, some thirty miles north-north-west of Dishforth. This brigade, however, went to Kenya earlier this year during the last Middle East crisis and has since stayed there; and another of the I.S. Brigades, No. 19, is now stationed in the Colchester area.

However, while No. 230 Sqn. is at present in something of a military vacuum and finds its day-to-day duties primarily those of airlifting senior Army officers, training goes on intensively for its main rôle. This consists of transport and logistics support for ground forces, casualty evacuation, and a new aspect which has recently been added—supply-dropping either by free fall or parachute. This has involved a small modification to the Pioneers, an exposed metal foothold below the door having been rounded-off by a quarter-circle bracket so that it will not catch anything ejected from the aircraft.

In its Army support rôle, No. 230 Sqn. is fully self-contained for maintenance in the field. All first- and second-line servicing is done by the squadron itself; spares packs are carried in the aircraft when away from base (as recently when two of them went to Germany); and it is estimated that the Pioneers could be operated out of reach of permanent stations for months at a time.

Up to now, the squadron has not had any opportunity of winning its spurs on active operations; but it takes part in field

Some of No. 230 Squadron's servicing personnel (below, left) with one of its aircraft at R.A.F. Dishforth. Right, the C.O. (centre) discusses the modification required for the Pioneer's supply-dropping rôle with six of the squadron members: from left to right, F/L. L. J. Hampton, D.F.C., D.F.M.; Sgt. T. C. Smith; W/O. C. P. Gilbert (W/O. i/c. Servicing); F/L. E. Douglas, D.F.C.; F/L. J. S. McC. Wallace, M.B.E.; and F/L. P. W. Good, who with F/L. L. Sandbach (not in the group) went with the C.O. to Germany on the visit referred to in the text



Two examples of the landing areas in the north of England used by the squadron Pioneers during exercises and training with the Army. The one on the left is known as Hilly Home; on the right is Gandale

exercises with the Army and has a clear idea of what is expected of it. In late July, at Fylingdales Range near Scarborough, the whole squadron was in the field and during operations with two T.A. brigades airlifted approximately 200 soldiers in four days. Then in September it undertook a small exercise with the 2nd Batt. Coldstream Guards (Household Brigade) at Otterburn Range.

Meanwhile, the pilots keep in trim for their job with continual practice. On the green triangle between Dishforth's runways (which in the past twenty years have been the exclusive preserve of heavy aircraft, from Heyfords and Whitleys to Halifaxes and Liberators and their present occupants), two 220 yd landing strips have been marked out for practice purposes. S/L. Simpson's aim is to train his squadron "to fly anywhere, at any time and under any conditions."

When recently the C.O. and two of his pilots, F/Ls. P. W. Goad and L. Sandbach, took two of No. 230's machines to Germany to operate with Army units there they found the Pioneers showed up very well in comparison with other types being used in the exercises. The Army Air Corps operated its Auster 9s, and in addition had a D.H.C. Beaver and an EP.9 on trial. The Army pilots who flew the Beaver had had only limited experience on the type, so it would not be fair to make too close a comparison; but it was found that the Pioneers could do everything expected of them, and in some instances were decidedly the most suitable for short-field operations.

No. 230 Sqn. has ten pilots in addition to its C.O., and all but one (a flight sergeant) are commissioned. The average age is quite high (35½) and the average flying experience—2,750 hr—is commensurate with it. Five of the pilots are ex-instructors and most of them have jet experience (one, in fact, having over 1,000 hr).

In this type of flying, the emphasis is more on take-off and landing than on duration of flight; the Pioneer's primary importance is as a close-support aircraft (though it has a comfortable duration of about 6 hr at 95 kt, which can be extended if necessary to about 8 hr). Thus the squadron's log for 1958 up to mid-November shows 1,350 hr flying and 4,130 landings (1,300 of them on unprepared strips), i.e., a rate of three landings for every hour flown.

That the Pioneer is a most useful aircraft was shown by a trip with S/L. Simpson from Dishforth to the Barnard Castle area. No. 230 has several fields up there, selected by the Army and approved by the squadron, and used with the consent of the farmers. None of them presents a permanent landing site, for the state of the ground changes with the seasons, and in addition to the regular hazards of wind direction (changing the approach available) the pilots have to keep a sharp eye open for ploughed surfaces and grazing cattle as well as obstructions like high-tension cables, trees, fences and telegraph poles.

On a fine, almost windless autumn afternoon we flew steadily north up the Vale of York. Visibility was excellent, but the lack of wind made it not the best of days for a demonstration of short-field landings. However, in the hands of a skilful pilot making a well-judged approach, the Pioneer pulls up after a very short run even in calm conditions. The technique is to approach in a nose-up touch-down attitude, giving a burst of power at the last moment to reduce the high descent rate and soften the three-point contact. Such a steep angle of approach makes the technique a little tricky, because the engine obscures the pilot's forward view. This difficulty was well illustrated when, at an Army camp, we made an approach on a concrete area shaped like a dumbell. When we were at about 50ft the area disappeared completely from view. In such circumstances, S/L. Simpson explained, one method is to approach the field at a slight angle until the last moment, provided there are no obstacles in the way. To add to our particular difficulty, what wind there was blew across the landing-area, which consisted of the narrow part of the dumbell.

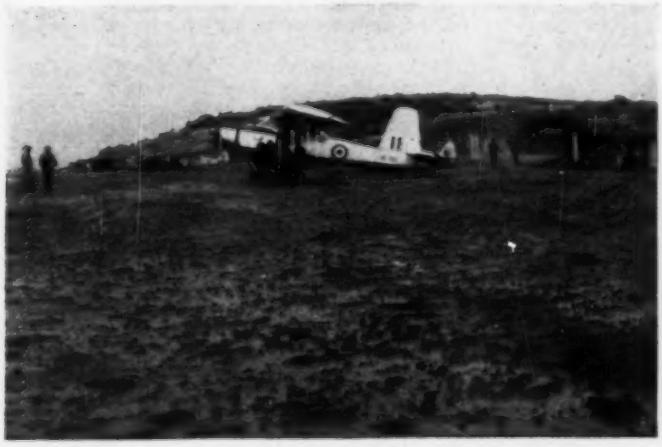
S/L. Simpson made five approaches on the afternoon's sortie, and two landings. One of these was in a fairly large field (as Pioneers go) near a river. Close by was an institution whose superintendent had recently complained about "dozens" of "old-fashioned type aeroplanes" flying over—actually one pilot of No. 230 Sqn. diligently practising strip landings in that locality. (These are often done at the rate of a dozen an hour in various directions into and out of the chosen fields.) The other site was far more tricky, with trees on the boundary, cattle in the field and a decidedly sloping surface. But with an approach speed of 25 kt and careful handling, aided by the generous area of leading-edge slats and Fowler flaps, the Pioneer went nonchalantly in and out.

This demonstration was, of course, given under good weather conditions; and though it helped to show off the aircraft's handling qualities, these are only half the battle as far as pilots of No. 230 Sqn. are concerned. More often than not they have to operate in bad weather when finding the way to a map reference (perhaps in hilly country, as is especially the case north of Barnard Castle), and this demands a high degree of pilot navigational skill.

On the return journey, S/L. Simpson exhibited the Pioneer's admirable slow-flying qualities, keeping the aircraft steadily airborne at about 20 kt with three aboard. One of the lighter sides of No. 230 Squadron's life is to allow astonished motor-drivers on the Great North Road to overtake them while they fly home low and slow with "everything out."

The squadron is now working-up in its new supply-dropping rôle, and the number of pilots and ground crew will probably be at least doubled in size when the Twin Pioneers arrive next spring. Then No. 230 is due to receive the Standard awarded to its flying-boat predecessor. With its new equipment it will be ready to support the security brigades in either tactical or conventional transport operations. What its future activities may be, or even whether it will continue to reside at Dishforth, are questions not yet officially decided. But meanwhile the squadron is preparing with the utmost keenness for whatever duties may lie ahead.

H. W.



Pioneer XL702 in muddy conditions at the Belgian Corps strip near Ludenscheid during the recent Army exercise in Germany

Straight and Level

CLEARLY, the Minister of Planes, Mr. Hugh Strangeways, is not going to budge from his decision to close London Airport. Despite the most vehement protests from a great number of responsible people, his mind is made up.

"I cannot afford to allow airline traffic to interfere with private flying from Croydon," he declares. "Of course, I am fully alive to the problems that this decision will create for the airlines. I am, therefore, glad to be able to announce that my department is giving active consideration to the question of alternative accommodation for them. In the meantime I have initiated the establishment of a special committee to examine the whole status of the airline industry in this country."

I know it is too late now, but I would like to draw the attention of Mr. Strangeways and his air traffic control advisers to the following facts.

There are three major airports at New York, all within a circle of ten miles radius — Idlewild, La Guardia and Newark. *Each* of these has more airline movements a year than London Airport. And yet the New York air traffic control system accommodates, or tolerates, two business airports, Teterboro and Zahns, *each* of which handles many times the number of movements recorded at Croydon. New York has air traffic control problems, certainly. But it does not try to solve them by closing down airports.

However, in reply to these points Mr. Strangeways will doubtless declare: "Air traffic control is the master, not the servant, of civil aviation."

● *"We have spent £3,000 million on armaments, a large whack of which has gone to the aircraft industry during the past six years, and we still have not got a single fighter plane that will shoot and fly at the same time."*—Mr. Denis Healey, M.P., on B.B.C. Television.

Three, five, perhaps ten million people heard Mr. Healey say this. And, no doubt, 99.9 per cent of them thought they were hearing a well informed politician imparting a true fact.

I do not expect all M.P.s to be well versed in aviation matters. But I do expect them to be certain of their facts when they make downright assertions like this.

● The Coroner at last week's inquest into the Southall Viking disaster is reported to have said: "I want to make it quite clear that I do not desire this inquest to be turned into a public inquiry."

He then proceeded to conduct an inquest which seemed to me to be very much like a public inquiry. Technical evidence relating to constant-speed-unit oil seals, etc., was sought and given, and aircraft log-book-record systems and other such matters were examined and discussed.

The strangeness of it all was that the Minister has ordered a full technical public inquiry into this very serious accident.

The inquest had already been delayed for three months. Could it not have been postponed until after the public inquiry? Highly technically qualified people are in any case going to examine the causes of the accident.

Approaching North Columbus Airport, Ohio, recently, in his Champion 7FC Tri-Traveler, seventeen-year-old Stephen Earl King was unfortunate enough to undershoot. A wire on the ground arrested his progress and, like a bowstring, twanged him backwards and upwards into some 138,000-volt high-tension cables. The final stage of this interesting and unusual manoeuvre—which the youthful aviator survived with bruises—is depicted here

● From *The Times* of November 26:

Amman, Nov. 25

"A Jordan military spokesman stated that a hostile jet aircraft early this morning dropped three bombs . . . in Jordan, and then flew across Israel and disappeared. The bombs exploded before reaching the ground."

Jerusalem (Israel side), Nov. 25

"An Israel Army spokesman said Israelis saw an unidentified aircraft dropping flares near the Jordan border."

If they weren't bombs, they were flares. And if they weren't flares, they were bombs. No problem—except the Middle East problem.

● The more familiar I become with Gatwick Airport's terminal the sadder I feel. I have no doubt that, functionally, Gatwick is as good as any airport anywhere; but aesthetically it is, in my opinion, a melancholy disappointment.

The basic principles of modern architecture—colour, simplicity, subtlety of texture—seem to have been overlooked. The terminal "finger" does not *have* to look like an elongated structural-test water-tank. The pillars and structure of the main building, and the poky steps up from the car park, do not *have* to be of raw untreated concrete. Why, then, are they?

Not having had the advantages of an art-school education, I do not know. But having seen quite a number of new airport terminals in the last year or two —Kano, Nairobi, New York International, Newark, Salisbury—I am sure that Gatwick need not have brought such little delight to the eye. I sincerely hope that L.A.P.'s new terminal will be a better monument to British architecture.

● We only think jets are noisy because there is nothing noisier. If you accept that, you will accept my answer to the jet-noise problem.

Radio Corporation of America, in an effort to find out how avionic equipment stands up to really loud noises, have developed a compressed-air loudspeaker which can generate the loudest controlled noise in the world—a mind-splitting 160 db.

If one of these were installed at each major jet airport, the general public would perhaps be a little more tolerant towards the 120 db whisperings of the big jets.

● I liked the story told by Mr. V. Christensen of S.A.S. at the Foreign Airlines Association Luncheon in London last week. It never fails to get a laugh when politicians are present:—

A centipede was suffering rather badly from rheumatism. He was advised to consult a well known doctor, a mouse. The doctor recommended the centipede to change himself into a mouse, thereby reducing his rheumatism by 96 per cent. The centipede expressed his gratitude, and asked how he could accomplish the transformation. "My job," said the mouse, "is to lay down general policy. The details I leave to you."

● Here is a postscript to Straight and Level's comments on Lockheed's new Electra brochure *Electrapedia*. From Bristol comes the following warning: "Perhaps it won't be long before your startled gaze falls on a copy of *Encyclopedica Britannia* . . ."

ROGER BACON

SERVICE AVIATION

Royal Air Forces and Naval Flying News

Change of Command

FROM March 1 next year, on the retirement of Air Marshal Sir Richard Ll. R. Atcherley from the R.A.F., Air Marshal Sir Hugh A. Constantine is to succeed him as A.O.C-in-C. Flying Training Command.

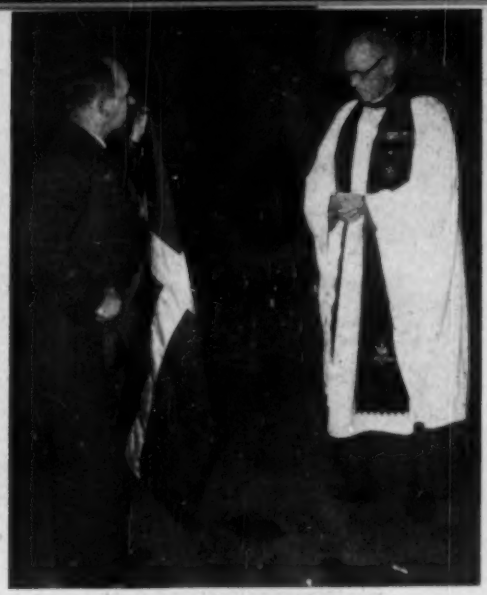
Air Marshal Atcherley's retirement will bring to an end one of the most colourful R.A.F. flying careers, spanning 36 years of military aircraft, from Sopwith Snipes in 1922 to the Hawker Hunter—in which he made a 50th birthday celebration flight four years ago. It has included an international reputation as an aerobatic pilot; setting-up a world speed record in the 1929 Schneider Trophy contest and a King's Cup victory the same year. During the war he commanded fighter bases in Norway and the U.K.; commanded No. 211 Group of the Desert Air Force and later at H.Q. Allied Expeditionary Air Forces adapted M.E. air tactics for the European invasion. He became first Commandant of the C.F.E., then first post-war Commandant of the R.A.F. College, Cranwell, was C-in-C. of the (then) Royal Pakistan Air Force and then Head of the Air Force Staff, British Joint Services Mission, Washington, before taking up his present post in December 1955.

His successor, Air Marshal Sir Hugh Constantine, is at present Deputy Chief of Staff (Plans and Policy) at SHAPE. Before taking up that appointment in May 1956 he was for nearly two years A.O.C. No. 25 Group, Flying Training Command. In 1930 he was a flying instructor at the R.A.F. College, Cranwell, subsequently carrying out three instructional tours at the C.F.S. He was a member of the school's inverted formation team in 1932, leading it in 1933 at Hendon. During the war, when he served with Bomber Command, he was awarded the D.S.O.

Regimental Commandant

SUCCEEDING A.V-M. J. L. E. Fuller-Good, who will be retiring from the Royal Air Force, A. Cdre. J. H. Harris is to be Commandant-General of the R.A.F. Regiment from March 1 next year with the acting rank of air vice-marshal.

First R.A.F. Regiment officer to have been appointed Commandant-General (previous holders of the post having been drawn either from other services or from the G.D. branch of the R.A.F.), A. Cdre. Harris has been Director of Ground Defence at Air Ministry since December 1955. An Australian by birth, he served in the G.D. branch of the R.A.F. from 1926 to 1930, when he transferred to the Indian Army. In 1938 he returned to the R.A.F., joining the Directorate of Ground Defence at Air Ministry when it was formed in May 1940. He then transferred to the R.A.F. Regiment on its formation in 1942. He is a C.B. and C.B.E.



Presentations (1): Mr. D. S. Ramanathan, Mayor of Penang, handing-over the keys of his official mansion to A. Cdre. K. R. J. Parsons, A.O.C. Butterworth; it will house a school for children of R.A.A.F. men at the base. At right, Col. J. B. Danielsen, Danish Air Attaché in London, presenting the Danish national flag, the Dannebrog, to the Chaplain-in chief of the R.A.F., the Ven. A. S. Giles: it is to hang in the R.A.F. church, St. Clement Danes

M.o.S. Weapon Post

BY agreement with the Secretary of State for Air, the Minister of Supply has appointed A. Cdre. W. R. Brotherhood as Director of Guided Weapons (Trials) in succession to A. Cdre. B. A. Chacksfield, who completes his tour of duty in the Ministry at the end of this year.

R.A.F. Postings

AMONG recent Royal Air Force appointments announced by Air Ministry are the following:—

G/C.s H. H. S. Brown to the Institute of Aviation Medicine, in charge of Aero Medical Training; F. D. Campbell to H.Q., No. 24 Group, as Senior Medical Officer; J. H. Lewis to Air Ministry, as Deputy Director of Aviation Medicine; J. F. Sandow to H.Q., 2nd T.A.F., as Deputy Principal Medical Officer; J. D. Tonkinson to R.A.F. Warton as Commandant, Medical Training Establishment; and A. M. Weston to H.Q., F.E.A.F., as Deputy Principal Medical Officer.

W/C.s A. J. Barwood to the Institute of Aviation Medicine; F. S. Krusin to the R.A.F. Hospital, Uxbridge, to command; R. Maycock to Ministry of Supply; R. W. Oxspring to Air Ministry, for duty in the Department of the C.A.S.; M. N. Phillips to the R.A.F. Hospital, Wegberg, 2nd T.A.F., as specialist in radiology; D. I. Pike to H.Q., Allied Air Forces Northern Europe, as Executive to the Chief of Staff; and T. H. Redfern to the Central Work Study Unit.

S/L.s T. H. Blackham to Northern Army Command as liaison officer (with acting rank of wing commander); F. H. A. Campbell to R.A.F. Weeton, for administrative duties (with acting rank of wing commander); T. de T. MacDonald to H.Q., Bomber Command, for technical staff duties (with acting rank of wing commander); C. D. Hinchliffe to H.Q., Transport Command, for administrative staff duties (with acting rank of wing commander); K. S. Law to Ministry of Defence (with acting rank of wing commander); and W. D. Reid to H.Q., Bomber Command, for technical staff duties (with acting rank of wing commander).

IN BRIEF

The Air Training Corps now has it own tie, bearing the A.T.C. falcon imposed on a navy blue background.

* * * * *

H.M.S. *Condor*, the R.N. air station at Arbroath, has now become the centre for mechanical training in the Fleet Air Arm following the recent closure of H.M.S. *Gamecock* at Nuneaton.

* * * * *

S/L. C. S. Macdonald is endeavouring to form a No. 2 Sqn. Dinner Club and would be glad to hear from all former and honorary members of the squadron. His address is: R.A.F. Selection Board, Cranwell, near Sleaford, Lincs.

Presentations (2): A. V-M. G. A. Walker, A.O.C. No. 1 Group, presenting a Vulcan model to Gen. H. S. Goker, C-in-C., Turkish Air Force, during the visit by a No. 83 Sqn. Vulcan to Ankara. Right, F/L.s A. E. Radnor and A. Biltcliffe, No. 17 Sqn., presented with Canberra models by Mr. F. D. Crowe, chief designer (Canberra), English Electric Co., Ltd., to mark their 2nd A.T.A.F. reconnaissance competition victory

CIVIL AVIATION

From Vickers comes this new picture of the Canadian Department of Transport's second 700-series Viscount. Attractively styled in pale grey, black and yellow, it will join another Viscount which has flown 2,700 hr since March, 1955

WAT LIMITATIONS

A YEAR ago, on November 29, *Flight* described the Government's new plans to bring the safety standards of the older transport aircraft more into line with present-day standards. These proposals have become known throughout the industry as WAT limitations, where WAT stands for weight, altitude and temperature.

The point about these safety precautions was that no right-minded operators objected to them in principle; rather were they endorsed. The objection, quite clearly, was a commercial one. It would not be an exaggeration to say that WAT limitations, once applied, would subject a half of the capacity operated by British independent airlines to crippling economic restrictions.

After many drafts, redrafts and postponements of the date on which these limitations were to be introduced, the Ministry last year issued its final proposals to the industry and announced that they would become effective as from January 1, 1959. It is now understood that the date has been further postponed—to March 30, 1960.

The British Airline Pilots' Association has commented on the matter in the following terms: "The Association is most disappointed and will keep a very close watch on the position to prevent the continuation of a situation in which an agreed standard of safety—one which has been agreed by all concerned—is made subservient to economics and commercial considerations."

B.A.L.P.A. say that WAT limitations have been under discussion for five years past and that "If the proposals to amend the regulations were intended to improve the safety standard of civil aviation, then we can see no moral justification for allowing them to be compromised by economic considerations, however crippling." The Association adds that it is "mindful of the loss of at least two aircraft whose performance was not supported by WAT limitations."

ANGLO-ITALIAN BILATERAL REVISED

AS already briefly recorded, the bilateral Air Agreement between Italy and the United Kingdom has recently been revised. Under an agreement signed in Rome on November 3 a special committee has been established, to be known as the Standing Anglo/Italian Joint Civil Aviation Committee; it is similar to that already existing between the United Kingdom and France. This body will meet at least once a year and (to quote a Ministry spokesman last week) "It is expected that this committee will provide a satisfactory forum for discussing amicably any disagreements or difficulties which may arise between the two countries."

The formation of this committee, notwithstanding the reassuring words of the Ministry, suggests that certain problems have arisen in the civil aviation relationships of the two countries. One of these, it is understood, is that the Italians have expressed dissatisfaction with their service between Rome and London. Alitalia operate only one service a day, and as this stops at Paris it is not really in competition with the direct services offered by B.E.A., or by B.O.A.C.'s transit services through Rome to points beyond. The Italians have been concerned at what they consider to be overwhelming competition, and at the recent talks it was agreed that the United Kingdom would now be willing to accept a direct Alitalia service between London and Rome.

It has been said in Italian aviation circles that Italy has been so dissatisfied with the situation that she has been considering the reduction of British capacity between London and Rome. One of the agreements now apparently reached, however, is that neither party shall act unilaterally in the restriction of services.

Another agreement is that Alitalia will in future be able to include London as a stop on their transatlantic service to New York. (In addition, the Italians' temporary permit to stop at London *en route* to Montreal has been confirmed.) It can be assumed that the granting of this traffic right is quite a big concession for the U.K. to have made; and it was presumably granted in view of the extensive Italian rights enjoyed by British carriers, as discussed above. Finally, the Italians have been granted permanent, as opposed to temporary, rights into Hong Kong—though not to Singapore, where Italy has no rights.

JET v. TURBOPROP IN IRELAND

COMMENTING on his recent visit to the Convair, Douglas and Lockheed plants in California, Mr. Jeremiah Dempsey, general manager of Aerlinte and Aer Lingus, emphasized that Irish Air Lines had not yet decided whether they would operate turbojets or turboprops on the North Atlantic. Referring to the failure of the recent Cannes conference to reach a decision on differential fares, he added: "Until the question of whether there will be different fares for different types of aircraft is resolved, the question of aircraft selection is one that could not be answered too readily. There is a school of thought which holds the view that, on such a competitive route as the North Atlantic, jet aircraft will win out unless the differential is quite substantial."

Mr. Dempsey went on to say that the question of the differential must be settled before April, when the new fares take effect. At present there was a differential of over 40 per cent between first, tourist and economy classes on the same aircraft. "I believe in differential fares for different types of aircraft," he said, adding: "Since there is a differential for extra comfort on the same aircraft, there is a good case for a differential between different types of aircraft. And, of course, it already operates at sea."

THE JETSTREAM

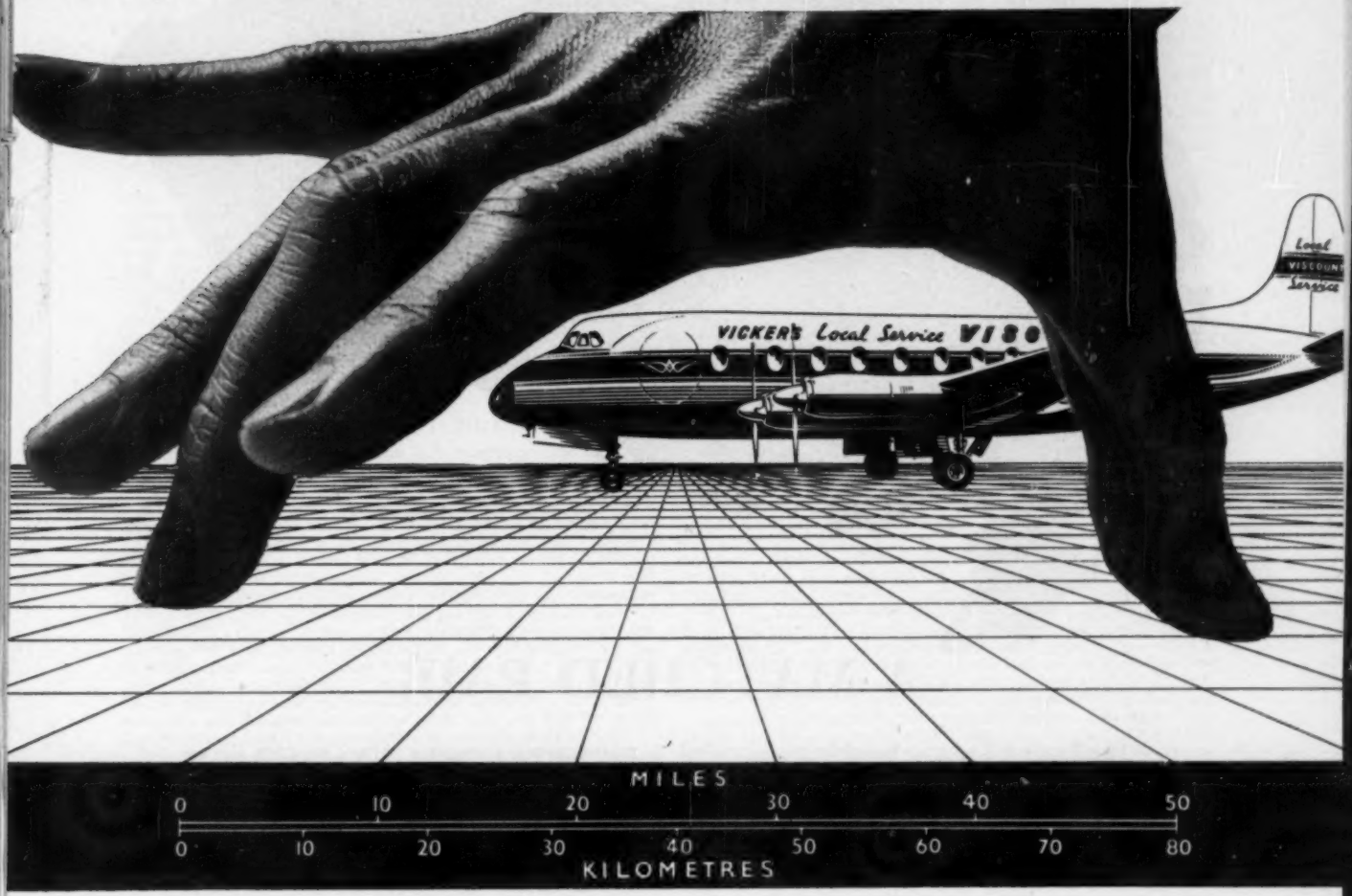
ON the evening of November 24 the meteorological superintendent of B.O.A.C., Mr. Ernest Chambers, M.B.E., gave a lecture at Church House, Westminster, on the subject of the jetstream. The meeting had been arranged by the Guild of Air Pilots and Air Navigators, and over a hundred meteorologists, air controllers, pilots, and others attended. The lecturer was introduced by Captain Bernard Frost of B.O.A.C., and was afterwards thanked by the Master of the Guild, Sir Frederick Tymms.

Although most of the study of jetstreams had been recent (Mr. Chambers explained), they were first described in 1933 by Bjerknes, and even during the last war proved a handicap to bombers—especially over Japan. A jetstream could be defined as an airstream flowing in a narrow tubular form at a speed above about 80 kt. The core of the stream was always associated with a marked temperature-discontinuity below.

In general terms it could be said that there were two main jet-

Jet-age labour pains: disputes with pilots, flight engineers and mechanics have recently caused or threatened strikes in seven U.S. airlines. Last week, T.W.A. and Eastern—as seen here—were grounded, Northwest and Northeast were threatened with strike action, Capital were just back in business after a strike, and National's stoppage had been narrowly averted. Lake Central were also in stewardess trouble

Now, even on the SHORTEST Sectors . . .



Viscount PERFORMANCE

Jet-prop travel with four-engined dependability, and a cruising speed of over 300 m.p.h., are among the main-line features which the Local Service VISCOUNT introduces on short haul routes. This new aircraft has been specially engineered for the best combination of climb, take-off and landing performance, and fast cruising at low altitudes. The Local Service VISCOUNT shares the same unique VISCOUNT background experience and offers the well-known economy and profitability of operation that have won approval with passengers and operators in so many countries.

For short sector, high frequency service there is no other aircraft which can offer a performance, passenger appeal and profitability comparable with the Local Service VISCOUNT

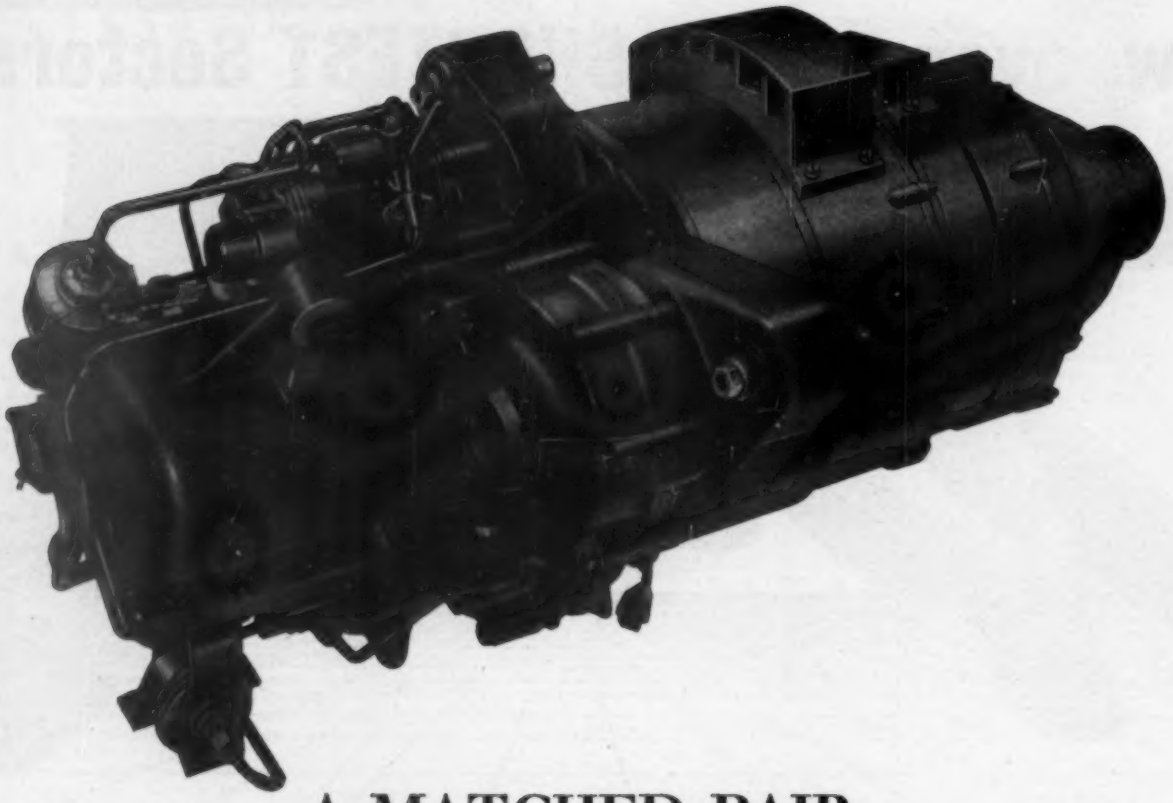
More Facts for Operators

- Field length only 5,000 ft.
- Engineered for high take-off and landing frequencies
- Up to five short sectors without re-fuelling
- Braking on three propellers while fourth provides starting power
- Extra high capacity internal start batteries
- Interior layout tailored to your operational requirements
- Seating for up to 65 passengers
- Storage for hand baggage
- Minimum demands on airport services
- Folding airsteps

The NEW
VICKERS Local Service VISCOUNT
FOUR ROLLS-ROYCE DART JET-PROP ENGINES

VICKERS-ARMSTRONGS (AIRCRAFT) LIMITED WEYBRIDGE SURREY

TGA/AT579



A MATCHED PAIR

The English Electric Brushless air-cooled Alternator, and the English Electric Constant Speed drive unit, together constitute a matched pair specifically designed to solve all existing problems of power generation and supply in civil aircraft.

The new Brushless Alternator ensures a new order of reliability, life between overhauls and maintenance economy. The Constant Speed drive unit (identical to the type used on the Boeing 707) is the well-proven answer to all questions of load-sharing between alternators on multi-engined aircraft, with all the ensuing benefits of dependability and safety margins. *Please write to us for full technical details of this matched—and matchless—pair.*

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CIVIL AVIATION . . .

streams, each associated with tropopause discontinuity: The polar, with an average height of about 25,000ft, and the sub-tropical, at about 40,000ft. Both of these might on occasion ring the globe, especially in the Northern Hemisphere. When these two combined, particularly in association with big temperature-gradients, really high winds were encountered. Thus, where the westerly airflow reunited after splitting round the Himalayas, and in association with the extreme thermal gradient between Siberia and the West Pacific, winds of up to 350 kt might exist. In fact, a Comet has under such conditions experienced 340 kt over the Sea of Japan. The highest recorded jetstream speed over the U.K. had been 240 kt over Stornoway, but 300 kt should be possible, especially when the stream was associated with a "blocking anticyclone."

In the Southern Hemisphere 300 kt had been recorded at Amsterdam Island, some 2,000 miles south-west of the Cocos Islands.

The lecture was profusely illustrated by slides, and it ended with a number of photographs, taken by Captain Frost, showing typical cloud-formations associated with jetstreams. Before these were shown, the types of weather were discussed, and the extent of wind shear likely to be experienced near a jetstream; this might well exceed 80 kt in 50 miles on the cold side, or 30 kt in 50 miles on the warm. The turbulence which such shear induced might, in some circumstances, be endured. But if a pilot encountered a jetstream bringing deep cold air from the north, and began to experience "cobblestone turbulence," he should be well warned that these were the conditions most likely to give severe clear-air turbulence—and that should be the time to reduce speed and to secure the passengers.

NORTHWEST'S EQUIPMENT PROGRAMME

IT has been known for some time that Northwest intend to buy five DC-8s and ten Electras. This purchase is now confirmed by the airline. Details are as follows:—

DC-8: Deliveries will take place from March to September 1960. Unit cost is $5,780,000, total price including engines and spares being $37,845,000. In return Douglas will buy back five Northwest DC-7s at a unit cost of $1.35 million, or $6,731,000 including "related inventory."

Electra: Deliveries will take place between July and December 1959. Unit cost is $2.4 million, and total outlay will be $29,654,000. Again Lockheed have arranged trade-in terms for Northwest's nine Stratocruisers, which will be bought back for $390,000 apiece or $3.5 million for the lot.

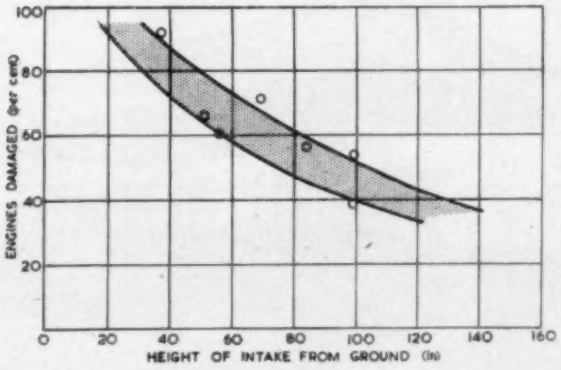
Both types of aircraft will be modified for increased range. The DC-8s will have a new wing leading-edge in the area of the wing root; this will increase tankage by 1,380 U.S. gal, and no doubt it will increase Mach number also. Gross weight is 310,000 lb.

The Electras will have 900 U.S. gal additional fuel to provide transcontinental capability. Take-off weight will be the highest at present certificated, 116,000 lb—a 3,000 lb increase over the figure for the standard model.

AIRLINERS AT WORK

AUSTRALIA'S scheduled airlines operated a fleet of 155 aircraft in the first half of this year. The annual overall utilization rate for this fleet—which includes types ranging from Rapides to Super Constellations—stood at 2,000 flying hours. This rate—almost certainly higher than that for any other country—must be one of the most important factors contributing to Australia's enviable position as the home of the world's cheapest air travel and the most profitable airlines.

The highest utilization rate (3,784 hr p.a.) was achieved by Ansett-A.N.A.'s DC-6 fleet (four DC-6Bs, two DC-6s). Next came Butler's three DC-3s with an average of 3,515 hr. Also exceeding the 3,000 hr mark were T.A.A.'s eleven Viscount 756s (3,068) and their three DC-4s (3,084). Other remarkable utilization rates were 2,913 hr for Qantas' L.1049s, 2,806 hr for MacRobertson Miller's DC-3s, 2,680 hr for T.A.A.'s Convair 240s, 2,456 for East-West's DC-3s and 2,301 for Butler's Viscounts. The relatively low rate (by Australian standards) of 1,800 hr for the country's entire DC-3 fleet is caused by the poorer figures achieved by the Big Three (Qantas, Ansett-A.N.A., T.A.A.): only one of the five smaller DC-3 operators failed to exceed 2,000 hr. These DC-3 rates are achieved on sectors averaging only 100-200 miles in length.



Entirely new standards of runway and taxiway cleanliness will have to be maintained if extensive compressor damage is not to be incurred by the underwing-podded jet engines of the big jets. This graph, based on information provided by the American NACA, shows the relationship between the percentage of overhauled engines damaged by debris, and the height from the ground of their air intakes

CONTROL OF ITALIAN AIRSPACE

NEW measures to improve the air traffic control situation over Italy have been accelerated as a result of negotiations between the International Federation of Airline Pilots' Associations and the Italian Government. The secretary of I.F.A.L.P.A., Capt. C. C. Jackson, whose headquarters are in London, returned from Rome last week with the belief that, "had the measures now proposed been in force at the time, the collision in October between the B.E.A. Viscount and an Italian Air Force fighter would probably not have occurred."

The measures proposed can be summarized as follows: (1) Military authorities will control commercial and military traffic; (2) establishment of a European Air Traffic Control Agency will be actively considered; (3) Italy's radar and radio-aids programme will be speeded up—including surveillance radar at Rome and Milan; the use of existing military radar to monitor civil operations; implementation of a network of 18 VOR stations, as recommended by I.C.A.O., with the aid of C.A.A. experts; and the installation of GCA and ILS at principal airports, again as recommended by I.C.A.O.

The disappointing feature of this programme is the continued administration of civil air traffic control by the military authorities. Though improvements and management of Italian A.T.C. will be financed and agreed to by the civil authorities, it is certain that few airline pilots—including Italians—will be happy in the knowledge that the safety of their passengers is in the hands of military personnel.

FLYING TO FUNCHAL

A DECISION at ministerial level is expected shortly on the future of Portugal's flying-boat service between Lisbon and Madeira. After the British independent Aquila withdrew their Solents from this route at the end of September (see *Flight*, October 3) the licence was transferred to Aero Topografica S.A. (ARTOP), a local company recently formed by Capt. Ferreira and Capt. Durval. (The Portuguese national carrier T.A.P. has no shares in ARTOP and merely acts as sales agent.) Two ex-U.S. Navy Martin Mariners were acquired, but one of them was lost without trace after only about a month's operation. ARTOP's service has subsequently been suspended and it is probable that their concession will be transferred to another airline. The most likely carrier to take over the service is Aerovias Aquila (a Portuguese private company financed by Senor Ataide) which is in process of taking delivery of Aquila Airways' three Solents.

BRITAIN'S SUMMER PEAK

FINAL figures are now available for British airline traffic in the peak month of August. These confirm the heartening trends suggested by the provisional estimates published by the M.T.C.A. in mid-October.

Total scheduled traffic for all British carriers in August increased by 11 per cent over the 1957 level. The two Corporations provided capacity well in excess of traffic requirements, but the independents were less optimistic and as a result enjoyed load-factors as high as 72 per cent on scheduled services and 90 per cent on inclusive-tour services.

B.O.A.C.'s load-factor for August fell to 59 per cent. As a measure of profit for the most favourable month of the year this figure is an ominous portent of the 1957-58 trading results to be expected by the Corporation. B.E.A.'s load-factor was considerably higher than that for B.O.A.C., but at 64 per cent was also well below the August 1957 level.

August brought a remarkable (40 per cent) increase in Atlantic traffic for B.O.A.C., but traffic on their African and Eastern routes fell by 1 per cent. B.E.A. and the independents experienced considerable improvement on international scheduled services; their domestic services, however, showed a slight deterioration. The fastest-growing single market was the independents' inclusive-tour business, which expanded by 43 per cent in August—and this figure is typical of the whole summer season's experience.

CIVIL AVIATION . . .

On these pages last week we forecast that the Boeing 707-320 Intercontinental will be rolled out "within the next few days." This event actually occurred at Renton, as seen here, as that issue went to press. The aircraft, N714PA, is the 16th 707 to be built

THE 880 NEARS ITS DEBUT

THE original programme for the Convair 880, laid down in April 1957, called for a maiden flight in January 1959. C.A.A. tests were to start in August 1959, and certification and delivery was to be accomplished by March 1960, preceded by a delivery for training purposes in November 1959.

Latest reports from San Diego suggest that this programme—like those of the Lockheed Electra and the Boeing 707—is ahead of schedule. Four aircraft, and a test specimen, are "rapidly taking shape." The first 880 is now aiming at mid-December for delivery to flight-test, two weeks ahead of the original schedule. Close behind is Convair 880 No. 2, which—minus engines, fuel and electrical systems—will be used for structural tests prior to flight-testing of the first aircraft. These structural tests will include checks of the flying-control system.

Convair 880 No. 3 is now in final assembly, and 880 No. 4 is following close behind. Meanwhile an 880 for water-tank fatigue-tests is scheduled for completion by February. Four other production forward-fuselage sections are now complete, the fifth and sixth fuselages having reached the assembly shop, and the fifth and sixth pairs of wings are nearing completion.

The present Convair schedule calls for 25 days between aircraft Nos. 4 and 5, and 23 days between Nos. 5 and 6. As production gathers momentum one 880 will be completed every 17 days.

DC-8 PROGRAMME

LATEST news about progress of the DC-8 is that the second aircraft will be flown this month, some two months behind the original schedule. The reason for the delay is said to be the decision to install the new type of combined sound suppressor-thrust reverser system designed by Douglas.

In the meantime, Douglas are installing what American sources describe as "experimental leading-edge flaps" on another of the DC-8s now being prepared for the test programme. This, no doubt, is a measure to bring the DC-8's take-off performance in line with the more stringent C.A.A. take-off requirements; it is unlikely to be a modification comparable with the leading-edge flap device fitted to the Boeing 707 to improve take-off characteristics at high angles of incidence. The Douglas programme is as follows:—

DC-8 No. 1. This JT3-powered aircraft has been flying satisfactorily at Edwards Air Force Base without interruption except for normal checks.

DC-8 No. 2. Also a JT3 aircraft, and bearing a United paint-scheme, this aircraft will be the first to be fitted with JT4 engines. This also is the machine which is being fitted with the leading-edge flaps. It will fly next month, after DC-8 No. 3.

DC-8 No. 3, which will be the second to fly, also has a United colour scheme and is being fitted with the new Douglas noise suppressor-reverser system.

DC-8 No. 4. A United aircraft, with JT3s, which also will fly next month.

DC-8s Nos. 5, 6 and 7. All these are for Pan American, and will participate with the above in the C.A.A. flight test programme.

DC-8 No. 8. This aircraft will be the first to be delivered—in June 1959 according to the original Douglas schedule. It will go to United Air Lines without its C.A.A. certificate (which is due to be granted in October 1959) for training.

DC-8 No. 9. This will be the first to be fitted with Rolls-Royce Conway engines.

FUEL FOR L.A.P.

THE new Shell-Mex and BP £600,000 fuel-storage depot at Perry Oaks, on the western boundary of London Airport, was officially opened on Wednesday of last week by Mr. Airey Neave, Joint Parliamentary Secretary of the M.T.C.A. When the main supply valve was opened 115/140-octane fuel was pumped along the three-quarter-mile pipeline to the storage depot in the airport central area.

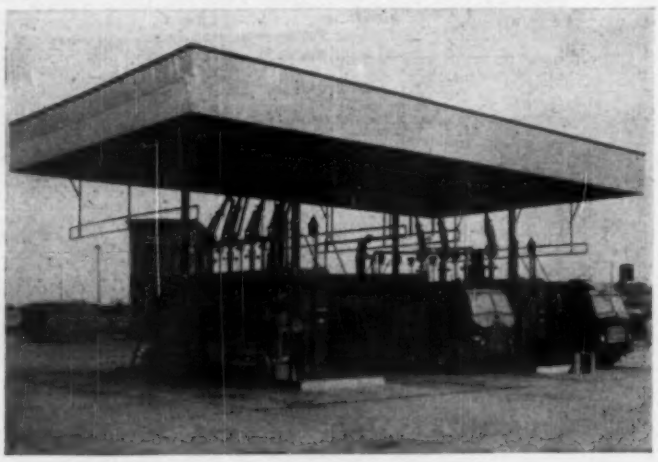
These depots, and another in the maintenance area, complete the first phase of the company's plans for supplying fuel at the airport. The total storage capacity of over a million gallons of gasoline and kerosine (the latter has exceeded the former in quantity since 1955), in addition to oil and water/methanol, is replenished from refineries on the Thames estuary and storage at Walton-on-Thames; the fuel comes by road, as many as 40 tankers a day carrying 4,000 gal each.

Supplies are brought to the aircraft by a fleet of 32 tankers holding up to 4,000 gal each and delivering up to 200 gal/min through each hose. During 1957 the company serviced 92,000 aircraft and supplied 36,000,000 gal of fuel; and at this year's holiday peak some 200,000 gal were pumped into airliners in a single day.

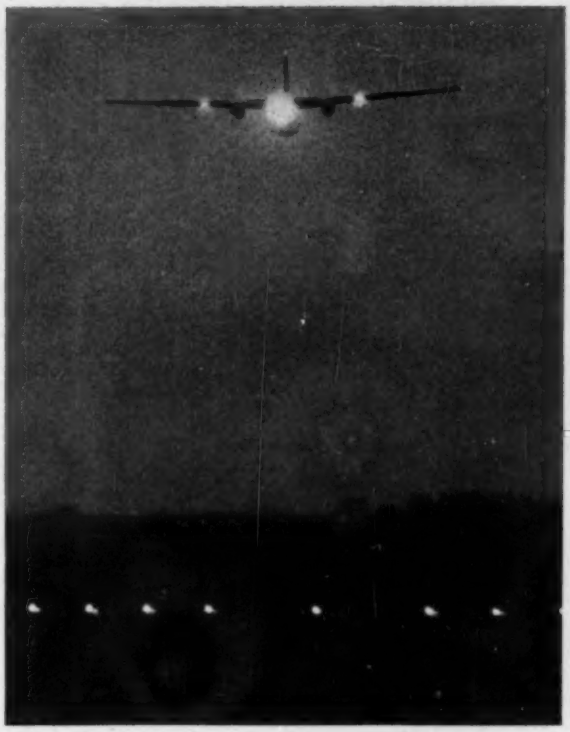
Though the amount of fuel delivered has increased ninefold in eight years, the period of expansion is by no means over. The big jet airliners may in the near future take on as much as 15,000 gal at one sitting and require a total delivery of 1,000 gal/min in order to keep turn-round time as short as possible. Tankers holding 6,000 and 10,000 gal each are now on order, but there is undoubtedly need for a hydrant system. This ultimate development, say Shell-Mex and BP, cannot be planned in any detail until aircraft loading areas are finally planned with the prospect of remaining undisturbed for several years.

It is, moreover, likely that the full requirements of the airport will increase more than threefold by 1966, and this would call for 150 four-thousand-gallon tankers each day to keep the depots supplied. Parliamentary sanction will therefore be sought to extend the existing pipeline that links the refineries with the Walton-on-Thames storage depot. Two six-inch pipes would be laid over the eight miles from Walton to Perry Oaks.

Before fuel leaves the refineries it is carefully checked for purity and further checks are made at every stage of delivery to the aircraft tanks. In accordance with A.I.D./A.R.B. requirements, detailed records are kept of every batch of fuel put into aircraft. All tankers at London Airport are fitted with V.H.F. radio and controlled from a central operations room, so that the right amount of fuel is ready for every aircraft as it arrives.



This is part of the new Shell-Mex and B.P. refuelling facility at London Airport. The picture shows a main loading gantry. A report on London's new fuelling arrangements appears in Col. 2 above



A new sight and a new noise in the Irish sky are the very newly delivered Fokker Friendships of Aer Lingus. Seen here at dusk on November 19, on delivery from Schiphol, and with nose landing light on, is the first to be delivered to Dublin, EI-AKB. Note the lead-in lights to Collinstown Airport. Aer Lingus have ordered seven

FOREIGN AIRLINES ASSOCIATION

TWELVE years ago, in November 1946, the Foreign Airlines Association was formed in London. Its aim was to provide a social and business forum for the many foreign airlines represented in the United Kingdom, and particularly in London.

The Association has since gone from strength to strength and now has a membership representing 37 foreign airlines. There are luncheon meetings once a month, and social functions are held regularly. Last week, on November 27, a twelfth-anniversary luncheon took place at the Dorchester Hotel. About 200 people were present, 150 of them guests of the Association.

Among those at the top table were the Minister of Transport, Mr. Harold Watkinson; Sir William Hildred, director-general of the International Air Transport Association; Sir Gerard d'Erlanger, chairman of B.O.A.C.; Lord Douglas, chairman of B.E.A.; and Sir Eric Harrison, Australian High Commissioner.

The most robust of the speeches came from Sir Eric Harrison, who replied for the guests. One of his light-hearted remarks was: "Who else but airlines would go to governments and say: 'Let us have another £10 million?' We just have to say, 'Come on, break it up chaps.'" Sir Eric spoke of the danger of letting too much air transport power "fall into the hands of the bureaucrats," and he gave some splendid examples of bureaucratic verbiage.

The Minister of Transport spoke entertainingly though without dropping any hints on new Government policy. On the subject of bureaucratic language, he suggested that he ought to get Sir Eric Harrison to write the next version of the M.T.C.A.'s Flight Time Limitations.

The toast to British civil aviation was proposed in generous terms by Mr. G. L. Craden of T.W.A. An extract from the speech by Mr. V. Christensen of S.A.S., who proposed the toast to the guests, appears on page 854.

BREVITIES

Air Algérie announce that they have taken up their option on a fourth Caravelle. Meanwhile, a previously reported order of 12 for Sabena is still being discussed.

* * *

Collins Radio Company, of Cedar Rapids, Iowa, has received a million-dollar order from Vickers for flight control systems and V.H.F. equipment for T.C.A.'s 20 Vanguards.

* * *

Boeing are to establish a spare parts pool at New York International airport in January for Boeing 707s and 720s. Situated near the airline operations area, it will occupy 6,600 sq ft and stock between 3,500 and 4,000 items.

* * *

December 7 is the date on which Qantas plan to implement the agreement with T.E.A.L. for chartering services between Melbourne and Fiji *via* Auckland. This move follows the N.Z.-Australian agreement relating to T.E.A.L.'s purchase of Electras.

* * *

B.O.A.C. plan to win "at least 50 per cent" of passenger air traffic between the U.S.A., Canada and the United Kingdom, according to the company's chairman, Sir Gerard d'Erlanger, last week. Some 4,000 seats are to be offered each week next year; by 1968 this figure will be 15,000.

* * *

New propellers designated X5 have been developed for the D.H. Rapide by Fairey Aviation. Thus fitted, the aircraft becomes a Rapide Series 6 with an increased take-off weight of 6,000 lb, and corresponding benefits in load and single-engined performance. Three such conversions have been carried out by Air Couriers, Ltd., of Croydon Airport.

* * *

The M.o.S. D.H. Comet 2E G-AMXD, Decca equipped, will demonstrate in Europe and North America next month, prior to the forthcoming I.C.A.O. discussions on the selection of an international short-range navigation aid. In the meantime, Comet 1A G-AOJU (ex-Air France) will continue the North Atlantic Dectra trials carried out by R.A.F. Valiants.

* * *

B.O.A.C. announced on November 26 the inauguration of jet services between the United Kingdom and Canada. These will start on December 19 on a once-weekly basis with Comet 4s between London and Montreal. B.O.A.C. add that forward bookings for Monarch flights between New York and London have increased by 50 per cent for December and January compared with the same period a year ago. About 1,500 passengers have now flown by Comet 4.

* * *

For the first time for 15 months, the U.S. load-factor went up in October 1958—to an estimated 60.2 per cent compared with 58.4 per cent in October last year.

* * *

A. Cdre. K. J. MacIntyre has been appointed U.K. representative of Fokker. Before his retirement last March A. Cdre. MacIntyre was Director of Policy (Air Staff) at the Air Ministry. His telephone number at 175 Piccadilly, London, W.1, is Hyde Park 1133.

* * *

In a recent Commons debate about the development of Prestwick the Joint Parliamentary Secretary to the M.T.C.A., Mr. Airey Neave, said that an extension of the existing 7,500ft runway to 9,800ft in the north-westerly direction had been provisionally decided.

* * *

A new Irish aviation company, Skycraft Services, Ltd., has been formed in Dublin "to operate aircraft and helicopters . . . and to act as brokers and agents." Directors are J. I. Yates and M. D. Yates. The former is Westland's agent in Ireland. Operations may start with an Auster 5 and an Anson.

* * *

The Canadian Minister of Transport, Mr. George Hees, has decided to establish a Canadian Airworthiness Council. Its chairman will be the chief aeronautical engineer of the Department of Transport. Its six other members will represent manufacturers (2), operators (2), pilots (1) and underwriters (1).

* * *

Aeroflot on November 20 carried out a Tu-104 proving flight on the Moscow-Cairo route in anticipation of regular services in association with Misrair. The Egyptian airline is at present studying the possibility of purchasing jet airliners for this and other routes.

* * *

Australia's domestic airlines were disrupted between November 20 and November 27 by a "rolling strike" of pilots as a result of a pay dispute. The strike was conducted on the basis of three days per airline, in contempt of a ruling of the Federal Arbitration Court, which promptly fined the Australian Airline Pilots' Association £A2,000. As *Flight* goes to press the situation has returned to normal.

CLUB AND GLIDING NEWS

ELSTREE FLYING CLUB's annual dinner last Friday was once again held at The Green Man, Kingsbury. Over 200 members and guests foregathered to dine and dance and listen to the commendably short speeches which are a feature of the club's night out. This brevity (it is strongly rumoured) is by order. David Ogilvy, Elstree Flying Club manager, is said to draw attention to speech-time limitations in one of the pre-briefing sessions that precede any of the club's operations.

The thoroughness which characterizes the club's activities and the hard work of David Ogilvy in particular were touched on in several speeches. The guest of honour, G/C. C. A. B. Wilcock, chairman of Derby Aviation, speaking on behalf of his fellow guests, said that the parent company just had to be interested in the club; David Ogilvy could be *so* trying on the telephone. On the whole, he said, he was disappointed with the progress of the flying clubs. Something of the fun had gone out of flying since the days of the S.E.5 and the Sopwith Pup. And the manufacturers had neglected the clubs terribly. What he would like to see would be cheap, safe and mass-produced aircraft, and much better landmarking on the ground to make flying a great deal easier.

Elstree, of course, is just within the London Control Zone and along with the other clubs frets at the restrictions which result. But symptomatic of the times, perhaps, was the presence of three guests from the M.T.C.A. among those on the top table. These included Mr. C. M. Colbeck, Southern Area Divisional Controller. Another guest with an interest in air traffic was Bob Easterbrook, the helpful and popular controller from Luton. It seems that at last air traffic control and private flying may be coming to terms. Once some of the mystery is removed (informal discussions with private pilots in their own clubhouses was one solution suggested privately at the dinner) and it has been demonstrated to offer them something of value, club pilots may even find it to their liking.

MIKE HAWTHORN is very much a man of the moment; it is a splendid achievement to have become Great Britain's first World Champion racing driver. He is also a pilot: he uses his Vega Gull to get around the circuits and on business trips.

On November 25 the Royal Aero Club gave a dinner in recognition of his achievement, and Gloster's Eric Greenwood, himself a very fast man indeed (he was the first pilot to exceed 600 m.p.h.), took the chair. In one of the few serious moments of the evening the chairman was warmly supported in his observation that Mike Hawthorn was "the epitome of skill and courage, qualities most admired by the Royal Aero Club."

On the right of the guest of honour sat Lord Essendon—Brian Lewis in his racing days—and it was he who introduced Hawthorn with, as he said, a "This is Your Life" speech.

Mike Hawthorn's reply was much appreciated, if largely unprintable. He recalled his first flights—in an Avian with his father—and mentioned that he had first started to build up hours (to his present 300) in a Fairchild Argus. It was one of his great ambitions to fly a Spitfire. (Since there is still an airworthy two-seater it should not be too difficult for him to realize this ambition.) He also mentioned that one day he would like to try air racing.

Before the evening closed Ron Flockhart, who has just been made a Grade 1 international racing driver and is also a pilot with his own Auster, had a few words to say about Mike Hawthorn's air navigation—as distinct from his driving.

FORMED five years ago by pioneer members of Lancashire Aero Club, the Woodford Old Associates held their fifth annual reunion dinner in Macclesfield on November 14. Among those present was Sir Roy Dobson, president of the Associates and managing director of the Hawker Siddeley Group. The health of the Associates was proposed by S/L. D. L. Armitage, the present chairman of Lancashire Aero Club, and the reply was made by Mr. J. J. Scholes, chairman of Woodford Old Associates. The following day members were the guests of the present management of Lancashire Aero Club at a luncheon at Barton Airport. Unfortunately fog prevented flying.

Air Marshal Sir Raymund Hart (left), hands the silver model glider to A. Cdre. G. J. C. Paul, founder chairman of the R.A.F.G.S.A. at the luncheon reported on this page

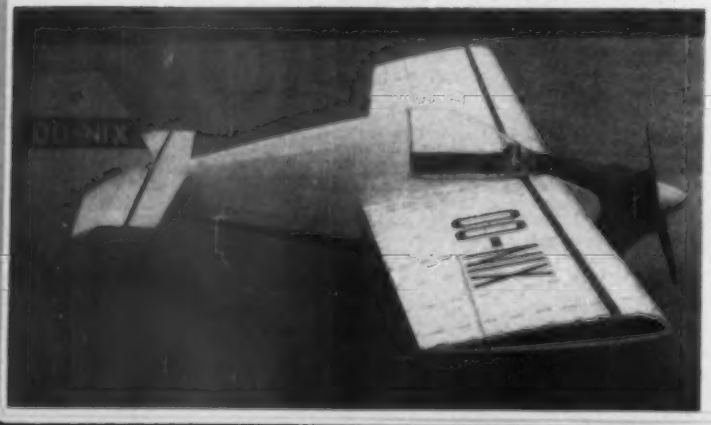
THE continued use of Perranporth Airfield for flying has now been assured, following a campaign by the Cornish Gliding (and Flying) Club to enlist public support for a particular tender when the Air Ministry offered the airfield for sale. The airfield has been purchased by Mr. E. Milner-Haigh of Carbis Bay, the father of one of the joint honorary secretaries of the club. The use of runways and grass strips will be granted to the club "at a low rental," and the cliffs and coastal strip area of the site will be made over to the National Trust. The club's campaign to support Mr. Milner-Haigh's tender resulted in 4,700 people signing petition forms, together with letters of support from many organizations and individuals including the Air League, British Gliding Association, Popular Flying Association, the Lord Bishop of Truro, the Grand Bard of Cornwall, Perranzabuloe Parish Council, the Western Commercial Horticultural Spring Show, the Overseas League, the West Cornwall Golf Club and St. Austell Brewery.

THE Popular Flying Association is holding an informal social evening variously described as a "noggin and natter" and a "beer and bangers affair" on Tuesday next, December 9 at the Kronfeld Club.

THE R.A.F. Gliding and Soaring Association recently gave a luncheon to A. Cdre. G. J. C. Paul in appreciation of his services to R.A.F. gliding. The president of the Association, Air Marshal Sir Raymund Hart, who is Controller of Engineering and Equipment at the Air Ministry, presented to him on behalf of all past and present R.A.F.G.S.A. members a silver replica of a sailplane. Sir Raymund recalled that A. Cdre. Paul had been founder-chairman of the Association on its formation on December 15, 1949, and had remained chairman until going overseas in 1957, when he was elected the Association's first honorary life vice-president. A. Cdre. Paul had now become secretary-general of the Air League of the British Empire, from which position, the president said, he would be able to continue to give his sterling service to British gliding.

Replying after his presentation, A. Cdre. Paul asked: "What is the R.A.F.G.S.A. worth? What does it achieve?" The answer he had found was a host of fine friends, but additionally three things which were of the greatest benefit and importance to the Royal Air Force. Firstly, the Association carried no "passengers." Everyone had to muck in and work. That called for enthusiasm and the spirit to give rather than to ask for benefits. Secondly, the opportunities for non-aircrew personnel to fly, even as passengers, were rapidly disappearing. The R.A.F.G.S.A. offered a replacement and the chance to fly as a pilot to any man or woman in the Service with the initiative and ability to try. Thirdly, the Association was a breeding ground for initiative and self-reliance.

Differences between the first and second Fairey Tipsy Nippers are visible in these photographs. Compared with prototype OO-NIP, its successor OO-NIX has an enlarged fuselage, enclosed cockpit and slightly revised rudder and elevators. It is powered by a Hepu-Volkswagen of 38 b.h.p. and the wings are wool-tufted for the current flight-test programme



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Flight, 5 December 1958

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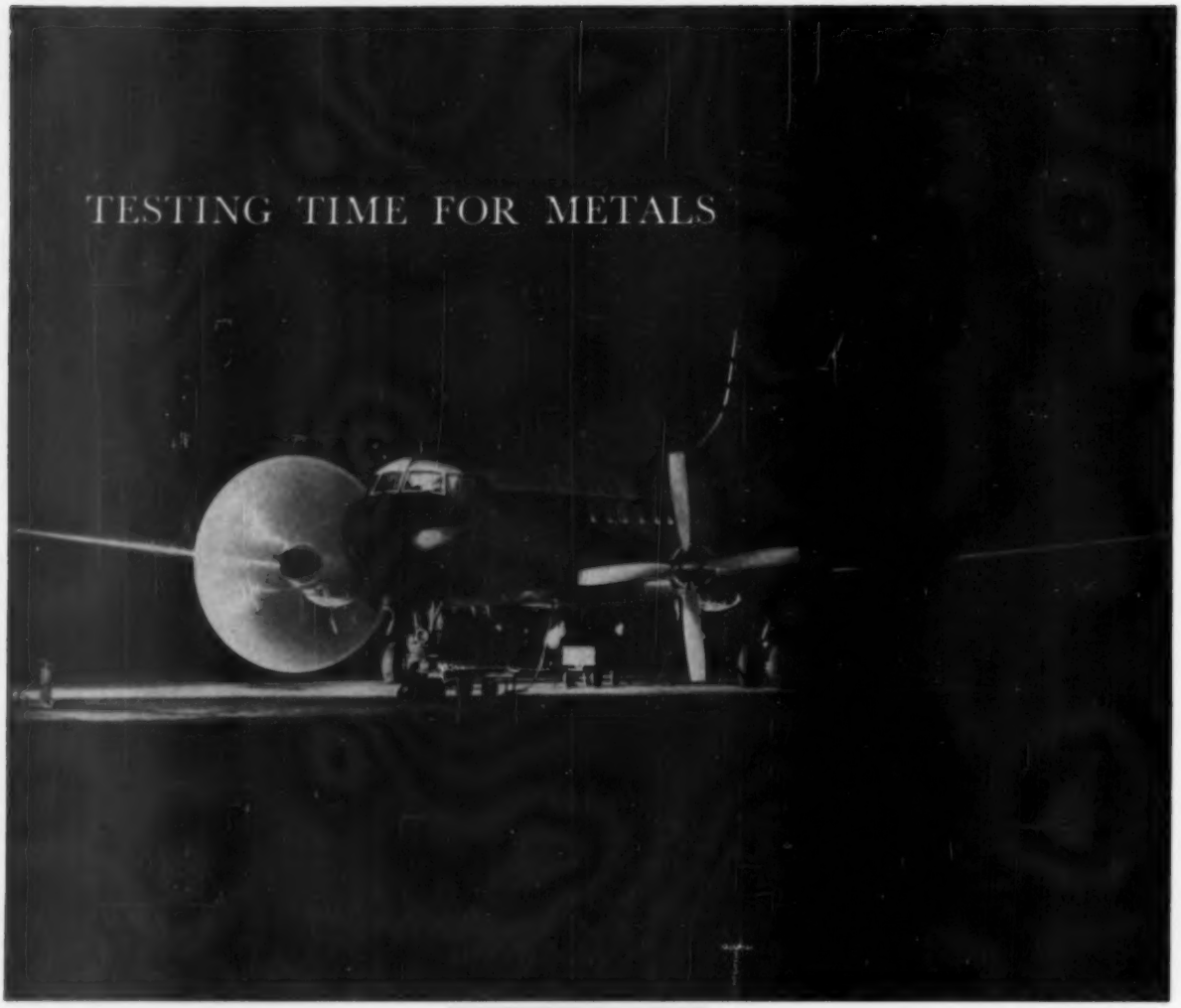
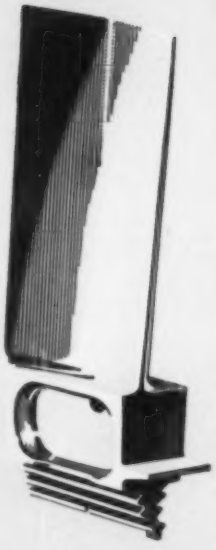


Ground-running the starboard turbo-prop of the Napier Eland Convair medium-range airliner.

Reliability is the prime requirement of any engine destined to fly on the air routes of the world. In the British airliners which have pioneered turbine air travel — and in several foreign commercial aircraft also—gas turbines of British origin are setting new standards of long life and freedom from maintenance. Their impressive performance is due in no small measure to the choice of Nimonic Alloys for the turbine rotor blades and other vital parts operating at the top end of the temperature scale. These alloys are unique in being backed by more than 15 years' experience of aircraft gas-turbine blade problems.



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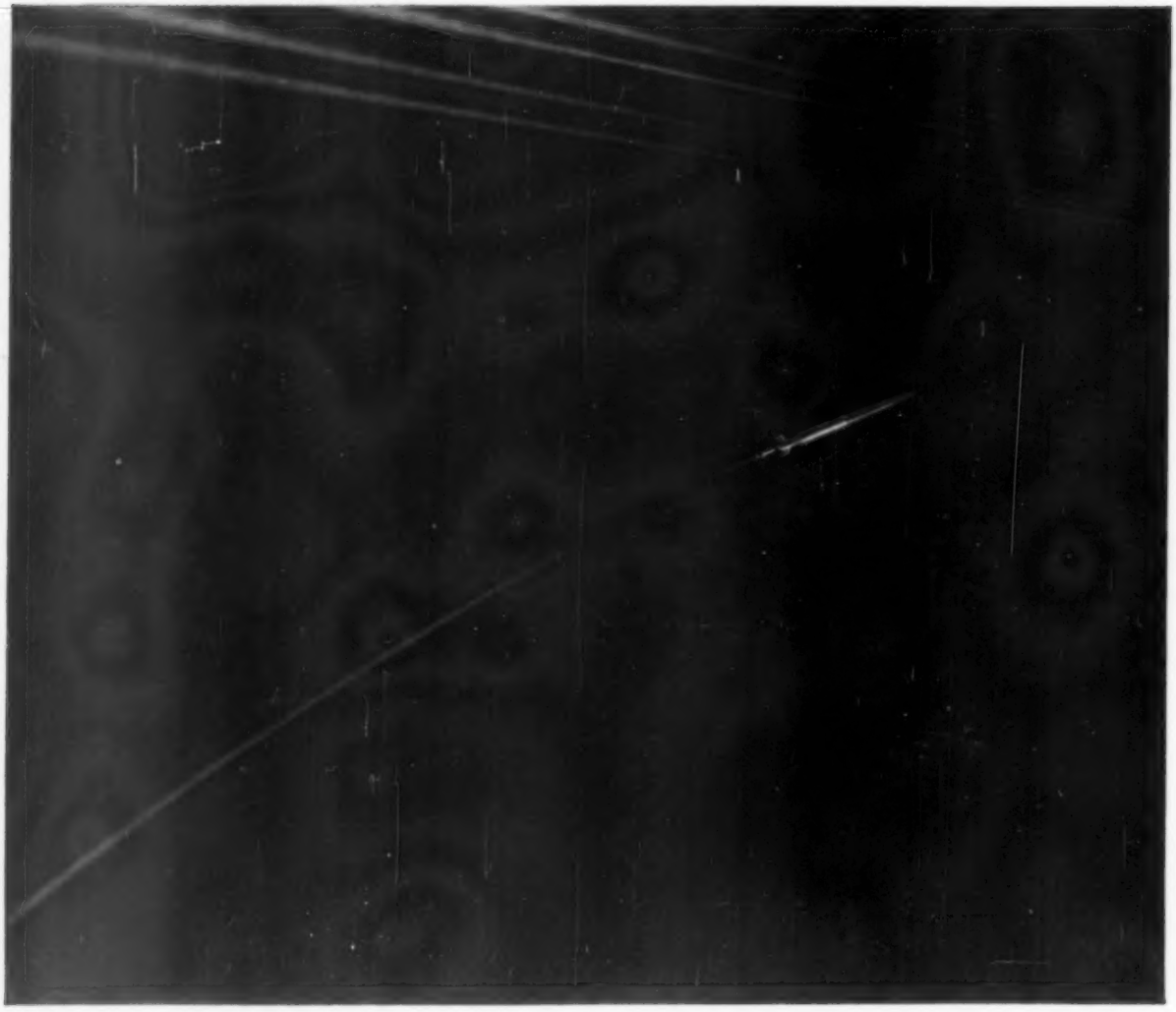

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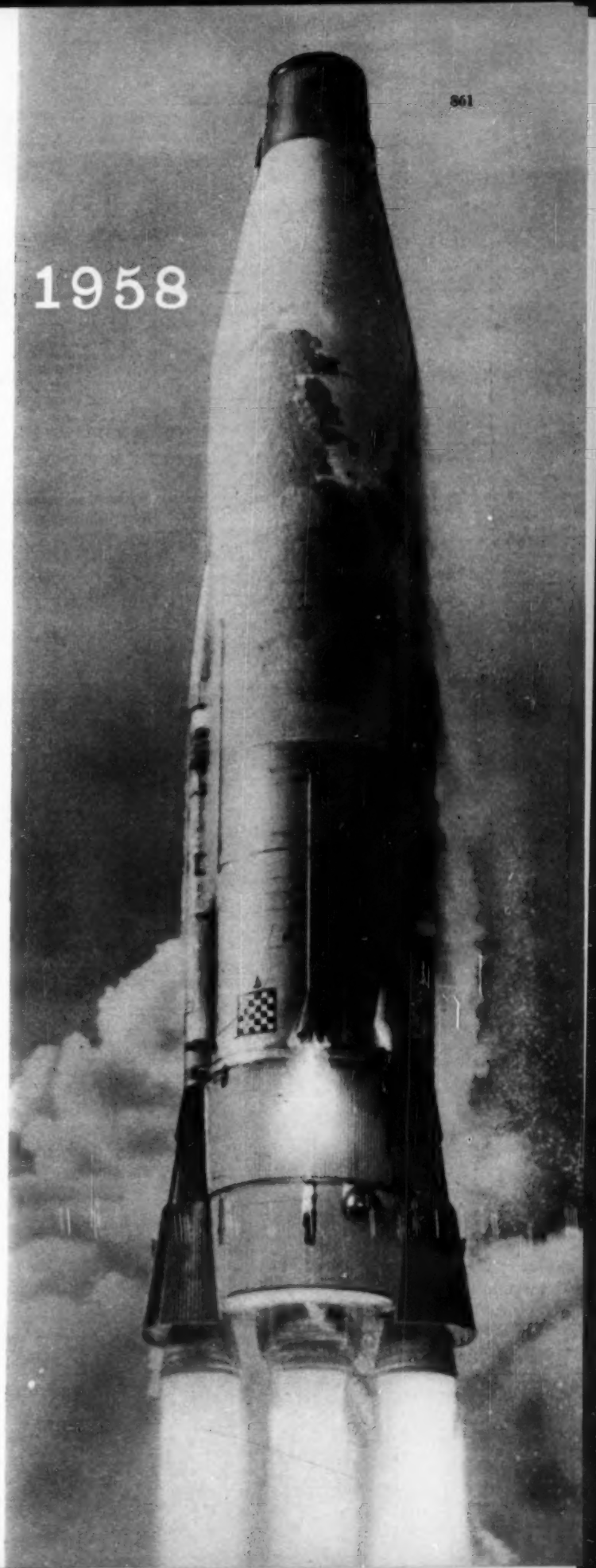
MISSILES 1958

IT is Flight's *custom at this time each year to present a survey of the world's guided weapons. Many of these devices —like the monster Atlas B illustrated on the right—have no wings, and thus have little kinship with the aeroplanes with which this journal has been associated during the past half-century. Moreover, all of them are engines of destruction, which in some cases can be so appalling as virtually to preclude their use by any thinking person.*

Nevertheless, this journal believes that such weapons have a rightful place in its pages. In the years ahead, everyone will become increasingly familiar with wingless flying vehicles; and it may not be very long before we can buy a ticket and ride in one. They are certainly contributing enormously to the science of flight in its widest sense, embracing as it now does movement both within the atmosphere and beyond it.

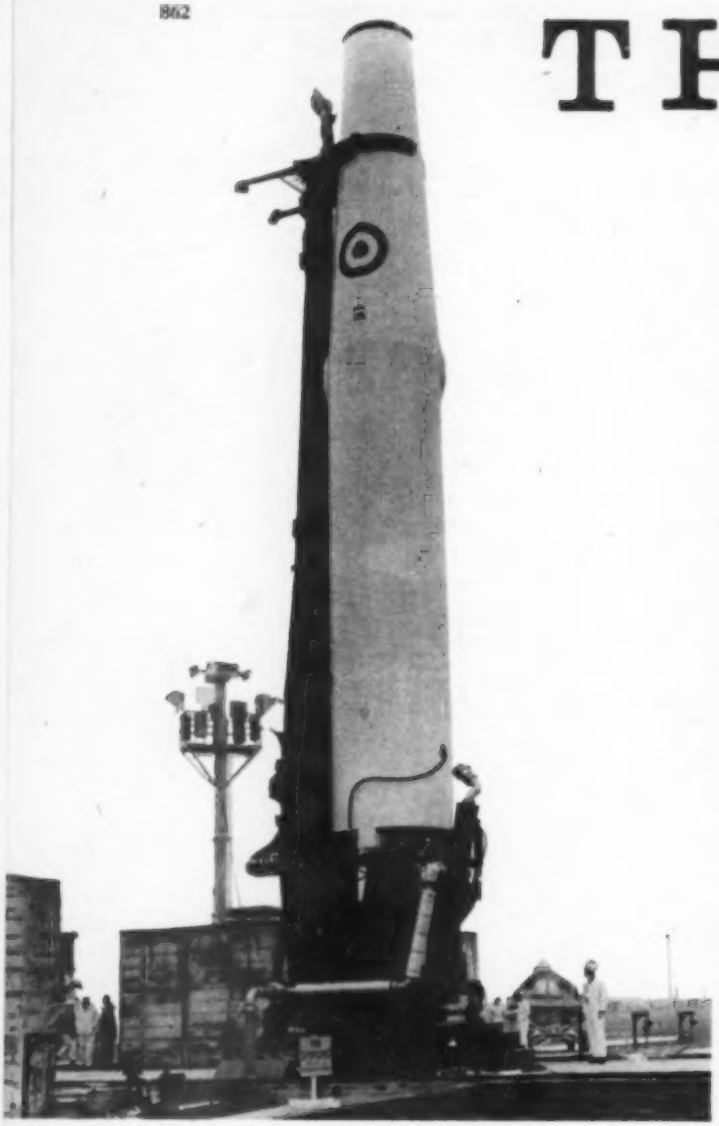
As these words are written the United States Army is working on a multi-stage rocket intended to place a useful payload in an orbit encompassing the moon. The U.S. Air Force failed in its three tries, although the second of these succeeded in sending the instrument package more than 79,000 miles from the earth, the greatest penetration into space yet achieved. The main carrier vehicle employed was based on the Thor intermediate range ballistic missile, which is this month strategically deployed in the United Kingdom with R.A.F. Bomber Command. The next eleven pages are devoted to a study of this weapon.

Following this feature, starting on page 873, is our international review of some 77 weapon systems, of which 45 are products of the United States of America. Their diversity and complexity is such as to leave a chronicler awed by the effort and expenditure daily devoted to their development. Yet it must not be forgotten that science has for centuries been spurred by military needs, and this trend is becoming ever more marked. Truly, the missiles of today will lead to the space-probes, and possibly transport vehicles, of tomorrow; and thus will missiles enter service for the benefit of mankind.



Right: the Atlas ICBM; above, the Vickers 891 to the same scale

THOR A STUDY



DURING the past four years the United States Air Force has spent about one thousand million pounds on the development of three long-range ballistic missiles. Taken together, these are the largest and most costly weapon programmes that the world has seen. The first of the three to become operational, the Thor intermediate-range missile, is this month scheduled to be deployed for service in the United Kingdom with R.A.F. Bomber Command.

One could argue that these vast programmes have been badly managed. The same amount of "deterrence" could have been purchased more easily and more cheaply, perhaps, had a little more thinking been done at early stages. In any case, it is impossible to assess such programmes independently. They have a potential far beyond the immediate task of producing weapons, for with them America has learnt how to move on to the next stage and conquer space itself.

It is no exaggeration to claim that the work already done has given the United States a commanding position in almost every field—structures, propulsion, navigation and guidance, ground-support equipment, operational training, supply and administration—which bear upon truly advanced vehicles, whether manned by human crews or not. In fact, for better or worse, all present evidence indicates that the U.S.A. is the only country outside the Soviet Union which, without external assistance, can hope to produce tomorrow's weapon systems—second-generation ballistic missiles, skip bombers, orbital winged vehicles, satellites and guided space vehicles.

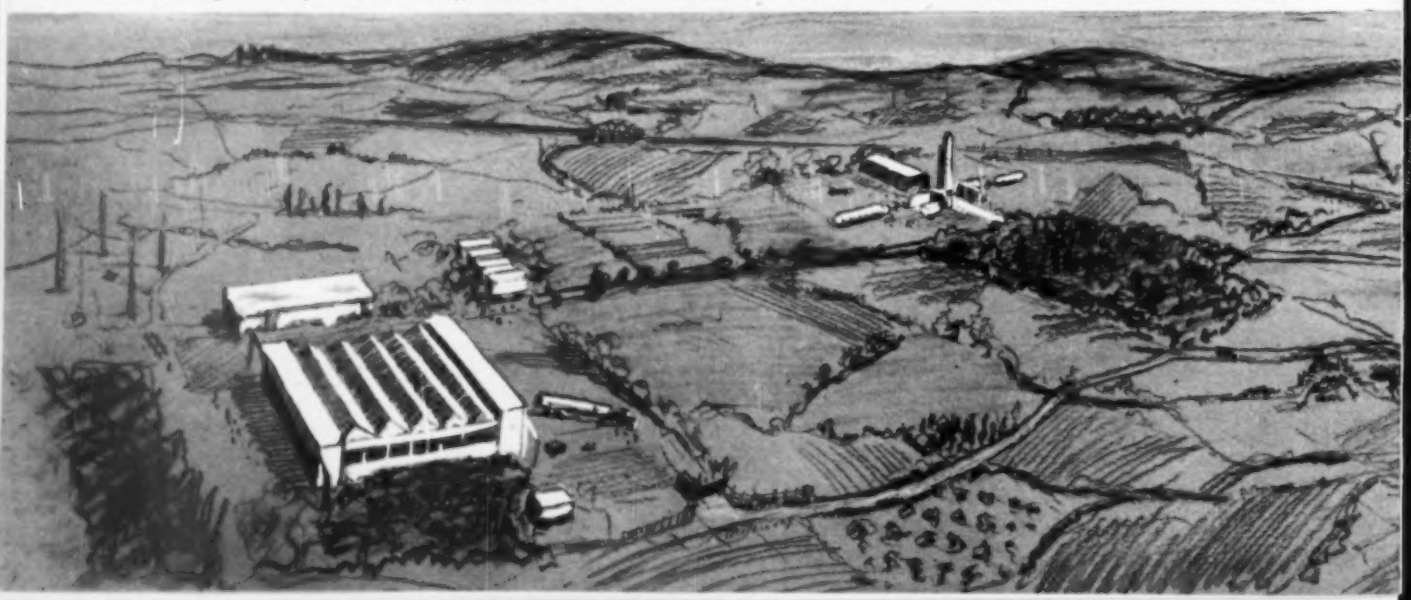
Leaving aside questions of a moral nature—which are not for the pen of a technical writer—it is interesting, to say the least, to note that Britain is the only Western nation at present actually deploying a strategic ballistic missile. The reasons for this are both political and geographical. As a study of the map shows, the U.S.A. is too far from the supposed potential enemy to employ an IRBM (intermediate-range ballistic missile), the range of which is 1,500 nautical miles; and the 5,500-n.m. ICBM (intercontinental ballistic missile) is not quite ready.

Thus it has fallen to our own Bomber Command to be the first in the field with these fearsome weapons. As already noted, the missile involved is Thor, and the following pages are devoted to a dissertation upon Weapon System 315A, of which the Thor missile is a part. Large portions of WS-315A remain classified by security, but in spite of this handicap it can still be shown that a ballistic-missile system is much more than just a ballistic missile.

THE BACKGROUND

MOST of the history of WS-315A has already been published—in particular, in our special missile review issues of December 7, 1956, and December 6, 1957. As a *modus operandi* this history affords an ideal example of the U.S. Air Force "industry" concept —as distinct from the former "arsenal" doctrine of the U.S. Army —in which virtually the entire management of a weapon-system

The panorama below portrays the possible appearance of uncamouflaged Thor launch emplacements in British countryside. In fact, the installation could hardly be concealed and would necessarily occupy several square miles. On the left are the RIM building and centralized ground-support trailers. Five launching sites are shown, three of them with the missiles ready for firing. It must be emphasized that the drawing is entirely unofficial and hypothetical, and bears no relation to any actual site which might be constructed in Britain or abroad



OF A GREAT WEAPON SYSTEM

A "Flight" Analysis

programme is assigned to a large private firm. In the case of WS-315A the firm is Douglas Aircraft.

For various reasons, Douglas's task with 315A was reduced to the basic business of organizing an army of subcontractors, developing the hardware within parameters already understood, and then, by persistent slogging, turning each piece of the system into a product capable of giving utterly reliable performance with a user squadron. In making such an assertion the writer has no wish to belittle the outstanding achievements of all who have worked on the system; he merely intends to point out that 315A accomplished few technological advances, nor was it intended to. The ground-work was largely already done, during the development of WS-104A (Navaho) and WS-107A-1 (Atlas).

In fact, to a very large extent, 315A was deliberately based upon the Atlas system, since it was deemed logical to cull for the IRBM programme the maximum possible amount of assistance from lessons already learnt, and thus permit the new missile to be developed to an extraordinarily compressed schedule. The decision has been proved a correct one; for, although the Thor and Atlas systems are of necessity ending up quite unlike each other, they have proved mutually complementary to a high degree. At the outset the IRBM appropriated major critical components of the ICBM as going concerns, and now Thor is actually assisting in the development of the larger weapon.

It is not difficult to see why the development of an ICBM was started first. The intercontinental delivery system, operating from bases inside America, has long been regarded as the primary U.S.A.F. weapon. In contrast, the IRBM pre-supposes overseas deployment. Moreover, other things being equal, the ICBM should pose much the more difficult scientific and engineering problem; it is always a harder task to make a longer-ranged vehicle, and the ICBM also has a critically high speed of re-entry into the atmosphere.

It was not until November 1955 that the U.S. Department of Defense gave the U.S.A.F. permission to develop an IRBM, and the contract for WS-315A was not let until a mere 36 months ago. (Development of the competing Jupiter IRBM was begun by the U.S. Army at about the same time, although Jupiter naturally had to make its own scientific and engineering discoveries as it went along. Jupiter and Thor have always been rivals, and it seems unfair that the Army weapon should have been wrenched from its sponsoring service and turned over to the service which already had Thor. As these words are written, the decision to cancel either Thor or Jupiter is awaited. The fact that this journal has chosen to devote so much of this issue to one of these weapons does not necessarily reflect our assessment of their relative merits. Thor just happens to be used by the R.A.F.)

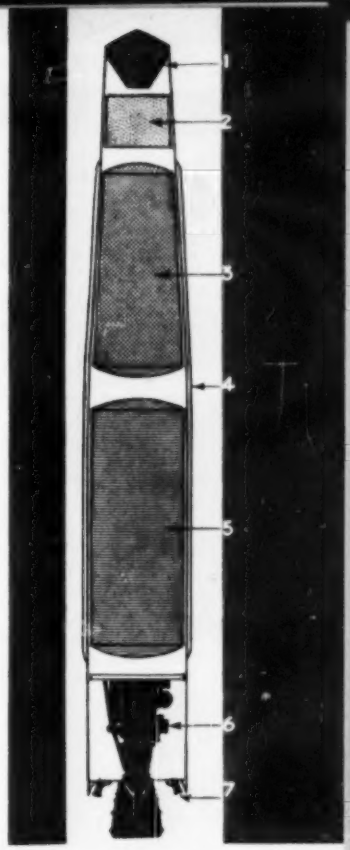
Be that as it may, the U.S. Air Force's IRBM system was initiated in December 1955 as WS-315A, and the vehicle was called SM-75 (strategic missile) and given the name of Thor. Development was put in hand following the usual administrative set-up, which is described by the Air Force in the following terms:—

"The Air Force Ballistic Missile Division (formerly the Western Development Division), Major General Bernard A. Schriever, Commanding, has the entire management responsibility for the Air Force ballistic missile program. The Air Force Ballistic Missile Division is the management member of a three-part team. The second member is the Ballistic Missile Office of the Air Materiel Command, which exercises all contracting and procurement responsibilities for the program. The Guided Missile Research Division of The Ramo-Wooldridge Corporation, the third member of the organization, provides technical direction and scientific supervision for the program, which now includes three inter-related weapon systems, Atlas, Titan and Thor."

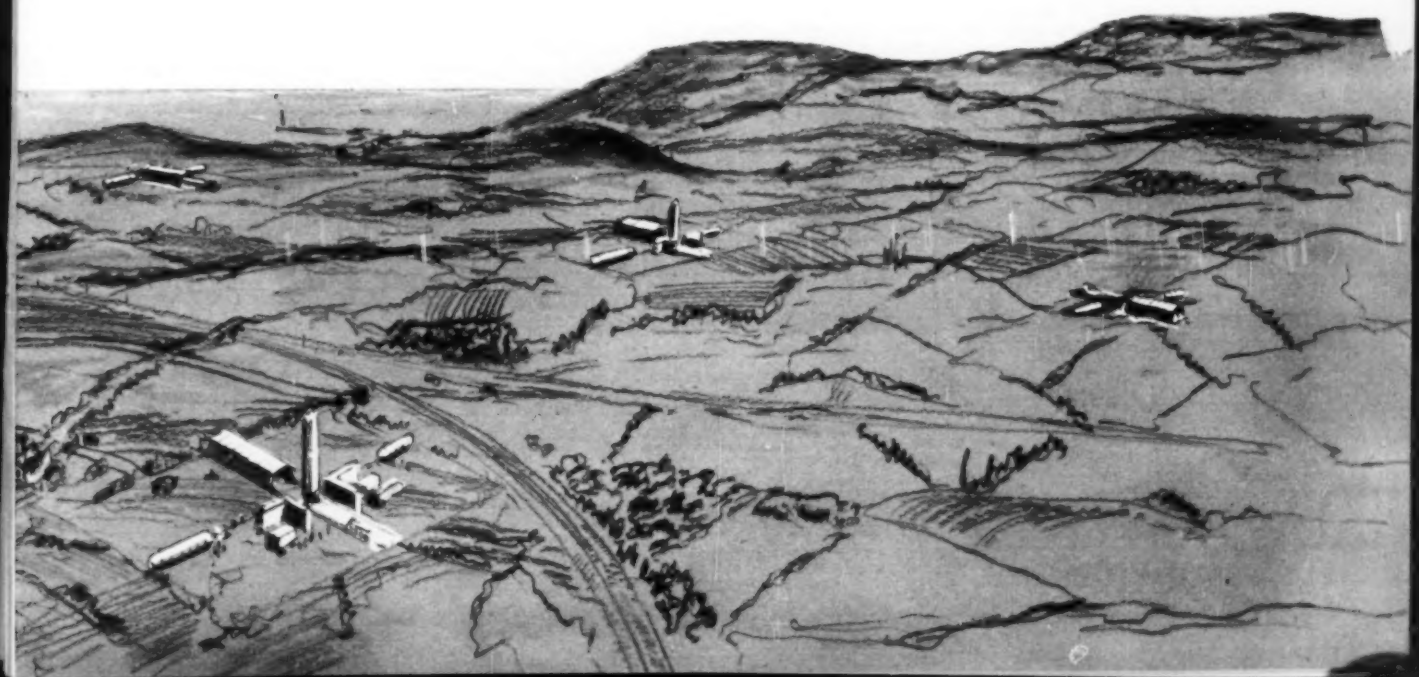
Western Development Division and Douglas signed the contract for WS-315A on December 27, 1955. Douglas's rôle was defined as that of "prime contractor, responsible for airframe fabrication, systems integration and ground-support equipment." Before the end of January, the Thor project team under J. L. Bromberg had determined the size and principal characteristics of the SM-75, and the engineering design was completed on the last day of July, 1956. By that date fabrication of XSM-75s was already in hand, using production tooling.

From the outset 315A was a "crash" programme and it was conducted at such a tempo as to form a deliberately calculated risk. More than in any previous project, the entire weapon system progressed in parallel—so that, for example, Douglas were calculating stresses in the airframe at the same time as another company was designing the struts which prop open the sides of the hydraulic supply vehicle. In theory such a policy saves time; and it is certainly an amazing achievement to have fired the first round within thirteen months, and to have equipped the first squadron overseas within 36 months, of the start of the project.

It was decided that the 1,500-n.m. mission could most efficiently be flown by a single-staged missile. At that time the longest-



This schematic diagram clarifies the location of each of the principal portions of the SM-75 Thor: 1, nose-cone and warhead; 2, airborne guidance; 3, RP-1 fuel tank; 4, external service duct; 5, liquid-oxygen tank; 6, main propulsion engine and turbo-pumps; 7, vernier motors



ranged single-staged weapons were the classic A.4 (V-2) and Redstone, over which SM-75 had to achieve a range extension of 600 per cent. Nevertheless, Douglas soon knew that this performance could be achieved, by employing new structural principles, a gimbal-mounted rocket motor (not subject to the drag of jet-deflecting control vanes), vernier motors to provide precise control of cut-off, propellants of slightly higher specific impulse and thin-walled integral tankage. Calculations showed that the desired payload of a thermonuclear warhead with a yield of 1 MT, i.e., equivalent to one million tons of T.N.T., could be projected the desired distance by a single-stage vehicle with a gross weight only a little greater than 100,000 lb, and with an overall envelope not too large for transportation by C-124 or C-133 aircraft.

In order to conform to the logistic policy already established by the U.S.A.F., the propellants had to be liquid oxygen and RP-1, a hydrocarbon fuel. The optimum sea-level thrust of the engine was calculated to be 150,000 lb, and it was fortuitous that the Air Force already had a suitable engine in an advanced state of development. This was a Rocketdyne unit, originally developed for the boost package of Navaho and employed in a modified form for the boost propulsion of Atlas. Selection of this basic design probably saved several months of development time.

AIRFRAME

THROUGHOUT 1956 the great team of missile engineers at the Santa Monica, California, plant of Douglas Aircraft were hard at work designing the optimum airframe for the new IRBM. On top of this they had to sketch the entire weapon system, in collaboration with the Ballistic Missile Office at nearby Inglewood, find people to make it and ensure that everything was accomplished on schedule. Even working out the schedule itself was a herculean task. Nevertheless, as noted above, the airframe design was ready to move into the detail stage at the end of the first month.

Following the conventional configuration, the SM-75 is made in the form of a large cylinder, which is stood upright before launching. Most of its bulk is taken up by the tankage sections. At the bottom of the body is the main engine and the two vernier motors, and above the tankage is the bay containing the airborne portion of the guidance system. Above that again is the warhead, inside the separable nose-cone, which is specially designed to withstand the arduous conditions encountered during its hypersonic re-entry into the atmosphere.

In the case of Thor the tankage sections occupy roughly 40ft of the overall body length of about 60ft, and the liquid-oxygen tank is underneath that for the fuel. Like all the longest-ranged ballistic missiles the propellants are housed within integral sealed portions of the fuselage itself; but, unlike the Atlas ICBM, the structural material chiefly used is not steel but high-strength aluminium alloy. Major tank sections are formed from stiffened panels each measuring 8ft by 25ft. Initially heavy slabs, each panel is stretched to relieve internal stresses and impart a curved cross-section, so that the finished panel can form a 45-deg segment of the fuselage (thus eight panels are needed to go right round the missile). The curved slab is then extruded to leave two axial I-stiffeners on the inner (concave) side and locking grooves along the longer edges, to secure the panel to its neighbours in a manner reminiscent of steel piling. Over 10 lb of metal is then etched from each panel by the U.S. Chemical Milling Corp., and the finished panels taper from bottom to top and have recessed areas with a tolerance on thickness of ±0.003in.

At the lower end of the fuselage is the cylindrical skirt. This houses most of the accessory power systems, four large pneumatic spheres, the vernier tanks, the gas-generator and turbopump and most of the main engine. To the skirt of most XSM-75s so far fired have been attached four delta fins, to increase the weathercock stability of the missile during the launching phase. These fins have now been found superfluous and have been discarded, with a considerable saving in airframe weight.

The lower end of the skirt is enclosed by a base-plate, in the centre of which is a large hole through which the main rocket chamber protrudes. Under the base-plate are mounted the two verniers, and six holes around its periphery locate with spigots on the launcher. Light-alloy forgings and doubler plates extending from these six points diffuse the weight of the missile into the surrounding structure; each socket is designed to accept more than one-sixth of the total weight, since side-loads due to wind cause asymmetrical loading. Similar diffusing systems are employed to spread the thrust of the rocket chamber; again asymmetric loading has to be allowed for, since the chamber is gimballed and its thrust-line does not always coincide with the missile's axis of symmetry.

Above the tankage the structure is similar to that employed in a modern monocoque fuselage. As this portion houses the airborne guidance system large access doors are provided, and these are stress-bearing much like the doors to an airliner. Doubler-plates and anchorages, together with the circular frames, carry the weight of the stabilized platform and remainder of the guidance system, which, as is outlined later in this account, is somewhat heavier than would today be considered necessary. Above this section is the final transition ring, in the periphery of which are three sockets to which the nose-cone and warhead are attached.

PROPULSION

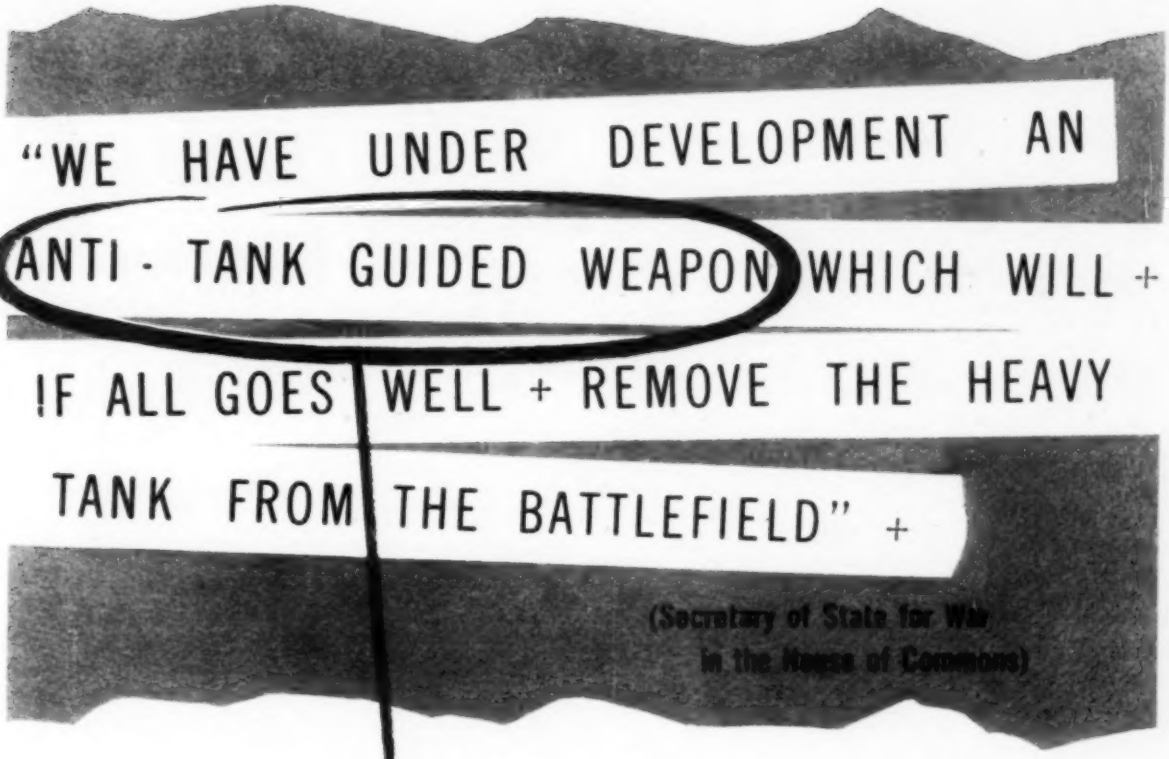
DESIGNING a sophisticated liquid-propellant rocket engine of 150,000 lb thrust is a major undertaking, and, as already noted, it is fortunate that the Thor engine could be based upon the design of powerplants previously developed during the Navaho and Atlas programmes. Nevertheless, the earlier engine had been designed to provide boost propulsion only, and the increased burning time in its rôle as a sustainer necessitated derating from 165,000 lb to 150,000 lb.

Designated LR-79, the Thor engine was evolved by the Rocketdyne Division of North American Aviation with extreme rapidity, and the first experimental XLR-79 was delivered for airframe-compatability tests in June 1956. Design and engineering development of the powerplant was undertaken at Rocketdyne's headquarters at Canoga Park, Cal., and static testing took place at Santa Susana and Leuhman Ridge (Edwards A.F.B.), and at Douglas's own facility near Sacramento, all these locations being in California. Production was assigned to the new Rocketdyne plant at Neosho, Mo., in June 1956, and production deliveries have been made from this factory since July 1957.

Like all the large U.S.A.F. ballistic missiles, Thor flies on a mixture of liquid oxygen (the oxidant) and RP-1 (the fuel). RP-1 is a light-cut petrol; it is the hydrocarbon fraction boiling between 380 and 525 deg F, and has a low aromatic content. The specification is MIL-F-25576A.

For convenience, the LR-79 can be considered to consist of two major portions: the upper, fixed section in which are situated the gas-generator, turbopump and auxiliaries; and the lower, gimbal-mounted chamber. The upper portion is built around a strong frame of welded steel tubes which transmit the thrust from the chamber pivot to the anchorage points on the missile fuselage. At present the upper attachments are rigid ball/socket fixtures, but anti-vibration mountings are likely to be incorporated in production SM-75s. From the main tankage the propellants are fed to the turbopump partly by gravity and partly owing to mild pressurization of the tankage by nitrogen supplied through a

All three chambers of Thor's propulsion system are visible in this striking photograph of a test-stand firing by North American Aviation's Rocketdyne Division. The two gimbal-mounted verniers are on either side, flanking the gimballed chamber of the main 150,000 lb-thrust engine. In front of the latter is the exhaust from the turbopump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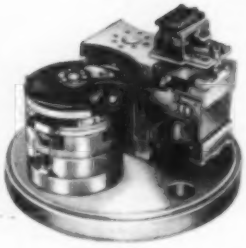

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reducing valve from high-pressure spheres in the lower fuselage.

Delivery to the engine is made at the correct pressure and rate of flow by the turbopump, which comprises two large centrifugal impellers mounted on the same shaft as a 2,500 h.p. single-stage turbine. The latter is driven by the gas flow from the gas-generator. Virtually a miniature combustion chamber, the gas-generator runs on the main propellants, but in order to restrict the gas temperature to the maximum permitted by the blades of the turbine, the mixture supplied has to have a considerable excess of fuel. For this reason, the exhaust from the turbopump—which issues from a nozzle alongside the sustainer chamber—appears as an irregular gushing flame, caused by the excess RP-1 burning in the free atmosphere.

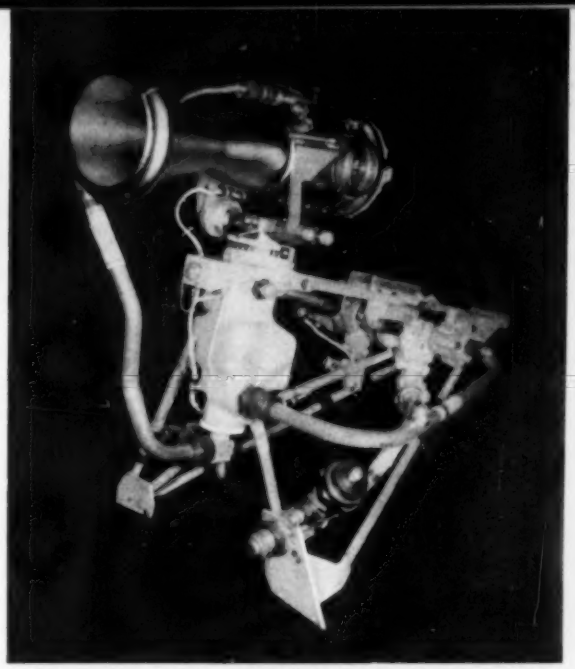
At the lower end of the thrust frame is the main universal gimbal to which the chamber is attached. Owing to the great size, extreme operating temperature and high internal pressure of these chambers, Rocketdyne were forced to adopt entirely new principles of construction. The method employed results in an assembly light in weight, relatively simple and cheap to manufacture and completely reliable in service.

Primary combustion takes place in a cylindrical section of chamber, which leads to the throat and then opens out into the main divergent nozzle with a slightly concave interior profile. Final nozzle diameter is about 40in. Manufacture of the chamber follows principles essentially similar to those employed by the traditional cooper (barrel-maker).

The entire chamber is formed from numerous longitudinally disposed 0.45in tubes in a heat-resistant nickel alloy. These are pressure-formed until their section becomes basically rectangular, varying in area from a maximum at the end of the tube near the nozzle of the chamber to a minimum at the throat and a gently increasing cross-section along the primary-combustion portion. Approximately three hundred of these tubes are then arranged around a vertical jig which has the profile of the interior of the finished chamber. The nickel tubes fit the jig accurately along their length and they are roughly held in place by a cycle inner tube slipped over them from above. The embryonic chamber is then lightly tamped with a mallet, and inspected to ensure that the inter-tube gap nowhere exceeds 0.0003in. Next, seamless steel bands are lowered over the assembly, and carefully knocked down tight like the hoops of a barrel.

Each tube is brazed to its neighbours with silver solder, extreme care being taken to ensure supreme quality of workmanship. The circumferential steel bands are then welded in place, their spacing being varied according to the internal pressure experienced by the chamber in operation; they are fairly well separated around the divergent nozzle but so close around the throat and primary (small-diameter) region that they form a continuous steel jacket in these areas, where combustion pressure is highest.

After being removed from its jig and allowed to cool, the chamber is turned on a lathe and its head is drilled to receive the bolts which hold down the injector plate. The latter is a large machined forging in high-strength steel, and it has to be finished with extreme accuracy. The completed chamber is subjected to an X-ray inspection and hydrostatic testing, in which the entire



The Thor vernier motor has a gimballed chamber, which is fed with lox and RP-1 through external pipes and thence via internal galleries

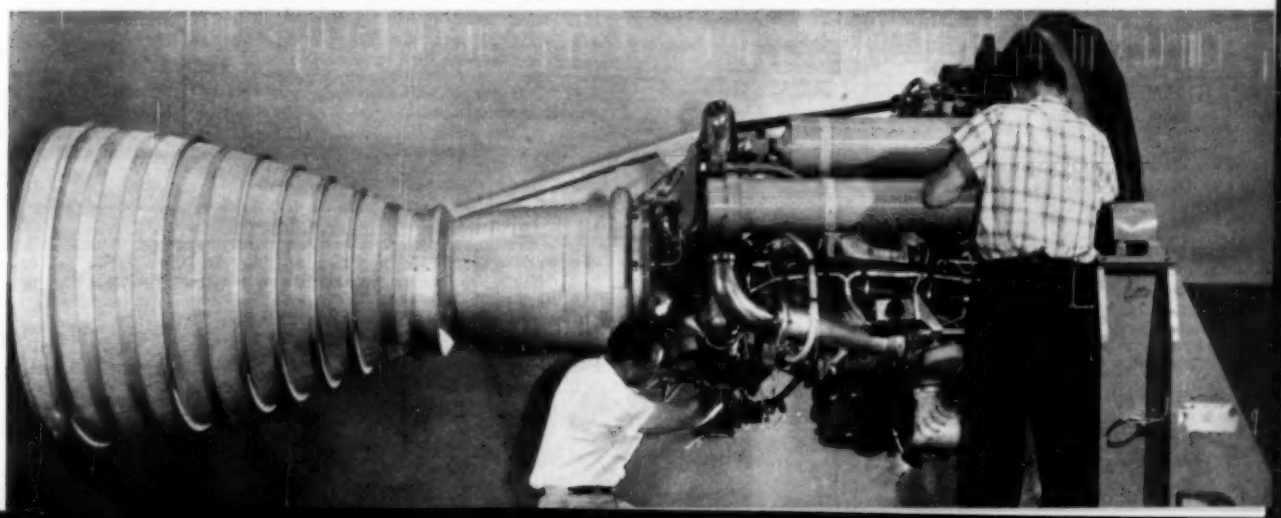
chamber is pressurized to 30 lb/sq in internally—to check for inter-tube leaks, not bursting strength—and 1,000 lb/sq in through the nickel tubes. Before running, the chamber is also calibrated by pumping water through the tubes at several selected flows up to 1,400 gal/min (in the reverse direction to that normally taken) so that the pressure-drop can be demonstrated as falling within the contractual limits. In operation, the 300 tubes of which the chamber is made conduct the RP-1 fuel to provide regenerative cooling.

Every production LR-79 is hot-tested in one of Neosho's two static-test stands. It is normally sufficient to run an engine for from 15 to 30 seconds, but after each batch of acceptance tests the stand is recalibrated by mounting an entire Thor propulsion system (including nitrogen-pressurized tankage but excluding the verniers) and completing a test run of 110 sec duration; this is probably less than the burning time required for a full-range mission. Further tests are necessary to prove the gimballing pivot, the moment of inertia of the chamber and the precise geometric centre, since all of these factors must be known for accurate guidance.

Gimballing of the big main chamber provides the coarse control essential during the early stages of a flight. Fine control during the major part of the mission, stabilization of the Thor about its roll axis and establishment of the missile on the precise trajectory at the required speed, are the tasks of the two vernier motors. These are small rocket motors, one of which is mounted on either side of the sustainer on a tubular structure attached immediately beneath the fuselage base-plate.

Each vernier chamber comprises an inner and an outer portion both spin-formed in 4130 steel. The outer casing is split longitudinally and welded over the inner, the space between them forming a passage for regenerative cooling by RP-1, which is constrained to flow spirally by a brazed-on helix of copper wire. The chamber is carried in a cast light-alloy yoke on the end of

Production of the big LR-79 sustainer is the responsibility of the Rocketdyne plant at Neosho, Missouri. A completed engine is here seen before despatch; the two horizontal cylinders are part of the integral starting system and the chamber is prevented from gimballing by a strut



The sequence of installing, erecting and firing Thor is outlined in the sketches on the right. The rectangular tinted area is intended to depict the environmental shelter which is rolled back before the missile is fired

The Thor arrives on its transporter/erector. Here, the environmental shelter is in its retracted position and the launching mount is in the upright, firing position. The latter would require extensive rectification between firings

At this stage the launcher has been tilted over and connected to the missile, and the transporter/erector has been raised off its road wheels, which are then removed, and connected to the launcher

a forged steel bar, motion about two axes being imparted by hydraulic actuators signalled from the main guidance system. Owing to the large arcs of movement involved, the vernier chambers are fed through galleries along the interior of the gimbal mountings, multi-land Teflon seals and vented spaces being used to separate the liquid oxygen, RP-1 and the hydraulic fluid used by the gimbal jacks.

GUIDANCE

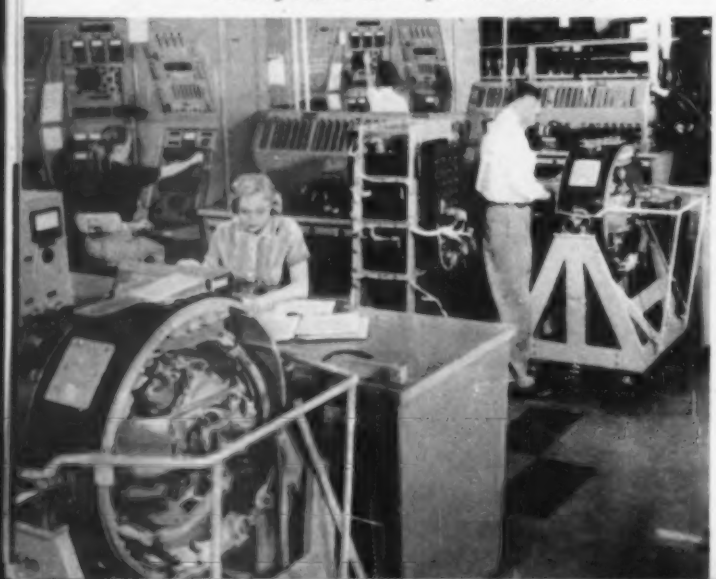
FOR the Thor the Air Force decided to utilize the AChiever pure-inertial system developed by the AC Spark Plug Division of General Motors in Milwaukee, Wis. This system is also employed in the Mace and Regulus II air-breathing, cruise-type missiles, and has proved itself to have high accuracy.

In the illustration below can be seen the main stabilizing gimbal assembly—which bears no relationship whatever to the similarly named units just discussed. Like the majority of vehicles with inertial guidance involving stabilized platforms with unlimited travel in three degrees of freedom, the gimbal of the Thor system has outside-in configuration, i.e., the stabilized components are carried on the innermost gimbal of the housing. The assembly carried by Thor incorporates three gimbals with 10^7 stabilization gyros (liquid-floated gyros with an angular momentum of 10,000,000 dyne-cm-sec) and three 10^4 acceleration-sensing gyros, one each for range, pitch and track.

The whole system had to be made appreciably smaller than previous inertial gimbal systems in order to withstand the high acceleration and vibration. It is of fundamental importance to appreciate that the abbreviated schedule to which Thor was developed did not permit the design of a wholly new guidance system, and the AChiever system adopted had to be built up from relatively proven circuits incorporating miniaturized gyros and accelerometer units.

There are, of course, three gimbal rings. Each is a light-alloy casting which, when machined and heat-treated, has the following tolerances: parallelism, 0.000025in; hole sizes, 0.0002in; hole spacings, 0.0005in; and angular relationship between gimbals, accurate within a very few seconds of arc. It is typical of AC's Milwaukee plant that the temperature of cutting heads has to be held within 2 deg F, and the close tolerances require dust-free and temperature-controlled shops. Each gimbal system contains over 700ft of wire and, although the complete airborne system is reported to weigh some 700 lb, it is some 75 per cent lighter than equivalent designs of two years earlier. It is unofficially stated that the airborne system costs about $180,000 per copy.

The inertial guidance system is produced chiefly at the AC Spark Plug plant in Milwaukee. In this photograph the stabilized platforms are being checked out in rigs which simulate the missile



On the three gimbal rings are provided supports for the torquing units, resolvers, synchros and potentiometers, these units being completely isolated on the stabilized platform from all movements of the SM-75 fuselage. Thin cables transmit data from the gyros and accelerometers to a pallet unit, which is a rigidly mounted (i.e., not stabilized), pressurized and air-conditioned package in which are housed the digital computer and its associated electronics, much of which is produced by R.C.A. The computer converts the signals into a form suitable for feeding to the hydraulic packages which gimbal the sustainer and two verniers. The hydraulic control system itself is a major mechanical achievement. Operating on special hydraulic fluid, it includes sustainer-gimballing actuators designed for operating loads of about 1,000 lb yet capable of control to within about ±0.005in. Rotation of each vernier about its roll axis is accomplished by a rack and pinion.

NOSE-CONE AND WARHEAD

ALTHOUGH it may seem a very minor part of the entire vast weapon system, in fact the nose-cone is the *raison d'être* for all of it; it is the payload, to which everything else is subordinate. Two functions are assigned to the nose-cone: it must house the warhead; and it must protect it during its searing passage through the atmosphere at its initial re-entry speed of some 10,000 m.p.h.

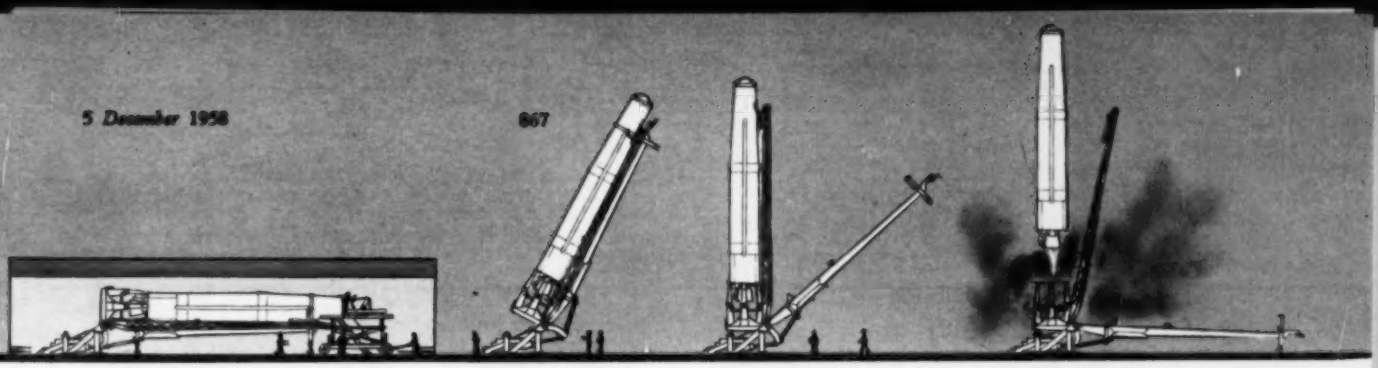
To some extent the SM-75 airframe design was planned in order that it might carry a nose-cone almost identical to that developed for the SM-65 Atlas. Responsibility for the cones of both missiles is vested in General Electric's Missile and Ordnance Systems Department. The MOSD's development—not production—contract for the Atlas and Thor cones amounts to $158m, and the units differ chiefly in the warhead contained and in the fact that the bulkier, higher-yield device inside the Atlas cone requires a corrugated re-entry section of body extending between the nose-cone itself and the Atlas fuselage (as the drawings on p. 873 show).

As in all long-range ballistic missiles, the Thor nose-cone is designed to separate from the remainder of the missile at a point after propulsion cut-off in the stark loneliness of space. When separation occurs it is essential that the missile fuselage should be decelerated by a slight retarding force (to ensure a complete break with the fuselage without departing too much from the correct trajectory), and the cone must also contain its own stabilization system to control its ballistic flight and ensure that it re-enters the atmosphere point first.

Actually, the cone does not have much of a point, as the illustrations emphasize. The relatively blunt shape adopted is the result of protracted research programmes by the NACA (now the NASA), General Electric and other agencies, and it represents what the Americans call a "technical break-through" of the first order. It was discovered three years ago that a blunt body travelling at hypersonic speed through the atmosphere can absorb heat as a heat-sink, and shed heat into the strong shock-wave which it creates, at a much higher rate than can a more pointed cone.

Thor at present uses the G.E. Mk 1 cone, which has an included angle of about 105 deg, a tip radius of about 12in, and a base diameter at the transition ring of about 60in. The forward-facing surface of the cone is believed to be manufactured from a special steel, and the heavy gauge employed is revealed by the fact that a 4,000,000-lb press is required by Lukens Steel to form part of the structure. The external surface is ground and polished to a very high finish. The resulting assembly has both the required high drag/weight ratio and a structure capable of resisting the intense kinetic heating encountered.

Inside the cone is secondary structure and the important inner liner within which are carried the warhead, the stabilization gyros and a great amount of instrumentation. The latter, both for the cone itself and for the warhead, is highly classified but is of



With the transporter/erector tug departed, the nose-cone transporter can be brought up and the warhead attached to the missile. The erector push-rod is engaged with the transporter chassis and the umbilical mast is attached

Under the thrust of the erector ram, the transporter/erector, umbilical mast and missile are smoothly raised into the vertical firing position, the cycle taking about one minute

After its upper jaws are released from the missile the transporter/erector swings down again, but remains attached. Fuelling proceeds and the umbilical mast feeds information

The climax of it all: as the Thor leaves the launcher the umbilical mast is pulled smartly away and the missile continues with all its internal systems functioning

sufficient complexity to require a special check-out trailer which during development is sometimes coupled to the nose-cone by way of the umbilical mast (described later) until the missile actually leaves the ground. Major portions of the nose-cone and inner liner are manufactured by Republic Aviation.

It is only to be expected that all details of the warhead should be classified secret, but enough has been written about such devices to enable a general assessment of it to be attempted. Like all large strategic missiles, Thor has a warhead of the thermonuclear variety, and it is reported that the standard pattern carried has a yield of one megaton. According to one report the latest thermonuclear devices weigh roughly half a ton per megaton yield, but the complete Thor warhead, with all its ancillary systems and instrumentation, probably weighs some 4,000 lb and occupies a spheroidal volume almost 5ft across.

In common with all American nuclear weapons the basic device is produced and handled under the aegis of the Atomic Energy Commission, and the exceedingly complex fusing and arming systems are developed by the Sandia Corp., of Albuquerque, N.M. It has been suggested unofficially that the neatest way of producing an atomic explosion—i.e. of triggering an uncontrolled chain-reaction—is not to slam two sub-critical masses together but to pack an almost-critical charge of fissile material in the centre of a substantial amount of ordinary high explosive. The concave interior of the surrounding h.e. acts as a shaped charge and, within a few microseconds of detonation, imposes enormous pressure all round the fissile core. The latter suffers an extremely sudden reduction in volume, of sufficient magnitude for it to acquire the characteristics of a super-critical mass, so that chain-reaction takes place; this technique is called implosion. Once the chain-reaction is started, further incredibly ingenious and highly secret processes may initiate the reaction of the fusion part of the device, which must involve heavy hydrogen (deuterium or tritium), lithium, or any of a variety of other light elements or mixtures. Once this occurs the cataclysmic megaton yield is achieved in a further few microseconds. (This may well be pure science-fiction; the true picture is shrouded, and requires specialized nuclear training to understand.)

Since the ballistic-missile blockhouses at the Air Force Missile Test Center at Cape Canaveral are designed to withstand the detonation of 100,000 lb of T.N.T. in direct contact, it may be that this is the yield of the initiating part of a thermonuclear warhead, i.e., the maximum partial fission which could take place following the accidental triggering of the device. Obviously, for the realization of the full yield it is necessary for all phases of the fission/fusion process to be completed, and stringent precautions naturally have to be taken to ensure that this can never happen until the missile is far from friendly territory. In fact, it is logical for final arming to take place during, or after, the separation of the nose-cone.

GROUND-SUPPORT EQUIPMENT

ALTHOUGH the G.S.E. sounds like a mere collection of ancillaries—which of course it is—it accounts for all but 13 per cent of the aggregate cost of the complete WS-315A. This may be unexpected, and it can best be explained by describing what the G.S.E. has to do during the handling of a missile by a user squadron.

According to the American journal *Aviation Week*, an operational squadron equipped with WS-315A should have fifteen SM-75s, plus five in reserve. All fifteen of the immediately available rounds are said to be stored actually in their launchers, in a T minus 15 condition, i.e., in a state of readiness such that each round could be launched fifteen minutes from the word to fire being given.

It will be appreciated that, since a ballistic-missile base is the first and most obvious target for enemy ballistic missiles, the reaction time (allegedly 15 min for Thor) is a matter of the first importance. For planning purposes, any missile which fails to get off the ground by the time an enemy warhead is scheduled to arrive (i.e., after 15 min) must be considered destroyed, and for this reason it is essential to keep as many missiles as possible in the T−15 state, and as few as possible in any other state—such as unserviceable. To some extent, reaction time depends more on effort, man-power and superb training than it does on the mechanics of the weapon system; although, of course, if it takes 12 hours to put the fuel in, nothing can reduce the reaction time below this value.

Possibly, a relaxation in the requirement—such that only five, instead of fifteen, missiles in each squadron had to be at T−15 readiness—might result in a cut in manpower of 50 per cent. At present, however, the only Thors that mean anything as a deterrent, as a means of hitting back, as a unit of bargaining power or anything else, are those in a T−15 state on their launchers.

Before any missile can be put on a launcher, its user has to sort out vast problems of logistics and "real estate." In Britain land is far from cheap, particularly if it has to be easily accessible by good roads. It must be left to the reader to decide where he would put the four squadrons of Thors which Gen. Norstad has said we are getting, but a glance at a map, and thoughts of what land the Air Ministry already owns, might provide some clues.

It should be emphasized that the drawing across pages 862 and 863 is purely hypothetical, and is certainly not intended to represent any real location. It is chiefly intended to show the following points: each missile has its own launching complex;

Taken at Cape Canaveral, this photograph shows the tip of an XSM-75 protruding through its service tower. The G.E. Mk 1 nose-cone is clearly visible; a spare cone is seen in the background

One of the largest indivisible portions of the WS-315A is the liquid-oxygen tank. Here, mounted on its wheels, it is going aboard a C-133A

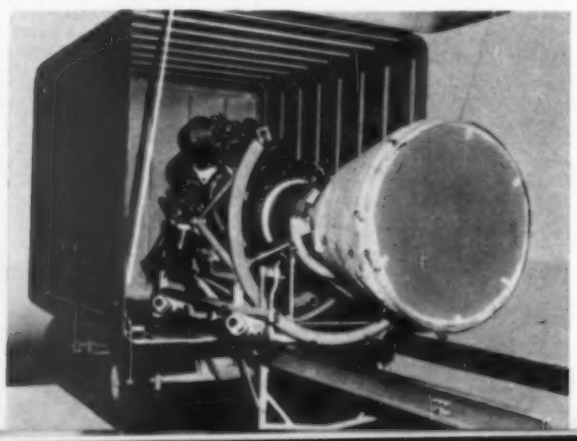
these complexes, containing missile, launcher, storage tanks, local supply and check-out trailers and shelter, must be quite widely separated; and there must be a centralized base from which the entire unit can be organized.

This base could include station headquarters, other administrative and domestic sections, and the receipt, inspection and maintenance building. Naturally known as the RIM building, this is the only real building of any permanence or immobility needed in Thor operations. Here, fresh missiles are accepted, inspected and passed out for their launchers, partly by connecting them to the awesomely intelligent missile check-out trailer and supplementary checkout (or SCOT) trailer. The former examines numerous missile systems during acceptance tests and routine maintenance, while the SCOT behaves as a perfect missile and compares itself with the real one to make sure that the check-out trailer is getting the right answers.

Assembly of the SM-75 missile takes place at the Douglas plants at Santa Monica and Culver City, Cal. Completed and inspected rounds are prepared for delivery with the main engine and verniers installed, but, naturally enough, without the warhead (which Douglas never see). For shipment the missile is mounted on its transporter (of which more anon) with no packaging save close-fitting half-shells around the sustainer chamber—which has a strut to hold it in its gimbals horizontally—and a waterproof plastic envelope over the complete weapon. In this condition the missile weighs surprisingly little and can readily be trucked across the ocean by the C-124s and C-133s of the Military Air Transport Service.

Once arrived at the destination airfield, the Thor must be taken to the location of its user squadron. It is assumed in planning the weapon systems of such missiles that a metalled road will be available, and so all that is needed is a transport vehicle. The Thor transporter—its full title of transporter/erector can be deferred for the time being—is an articulated trailer towed by a standard 6×6 tractor. The transporter frame is fabricated in steel to a high degree of precision, and it has great rigidity for a light weight. It carries the missile in a horizontal position, nose-first. Most of the missile's weight is taken by the rear attachments, which are bolted to two of the launcher-locating holes in the base-plate. The remaining support is provided by a front mounting in line with the strong bulkhead behind the guidance section, provided with left and right clamping arms which fit closely around the fuselage to prevent lateral movement. These jaws each have a spigot to hold the missile, and they are opened to release their charge only when the latter is standing vertically on its launcher.

In the photograph below the complete main engine is being roll-transferred from the work-stand to its Mobiltainer (mobile container)



About 30 per cent of the weight of the missile and transporter is borne by the large pivot by which the transporter is articulated to its tug. The remaining 70 per cent rests on the two pairs of rear wheels, the tandem units on either side of the chassis being hydraulically steerable. Ahead of each tandem pair is seated a rear steersman, whose task it is to assist in the circumnavigation of winding tracks, and in particular to guide the rear of the transporter as it is reversed on to the launcher.

The launcher is the hub of the complete firing complex. It comprises a 30,000-lb stand which supports the weight of the missile while its tanks are being filled, and holds it clear of the ground so that the rocket engines can operate effectively. In fact, its design is complicated by the fact that the missile has to be brought in horizontally and fly out vertically. For this reason it is divided into a fixed lower portion and a hinged upper portion.

Contractor for the complete launcher (and for the transporter/erector) is the Ordnance Division of the Food Machinery and Chemical Corp., at San Jose, Cal. They are proud of the fact that, eight months after receiving the contract from Douglas in January last year, they delivered the first production equipment two months ahead of schedule. Their design looks as strong as a battleship, yet it is fabricated to a high degree of precision. An accompanying picture (p. 870) shows the launcher-erector, the fixed lower portion of the launcher, in company with the hinged part. While en route to its final destination this component is mounted on four pairs of wheels, and a towing arm is provided for ground handling. It is fabricated from welded steel sections, and consists of a fixed base carrying a hydraulic ram capable of exerting a thrust of some hundred tons on an arm suspended from an upper pivot.

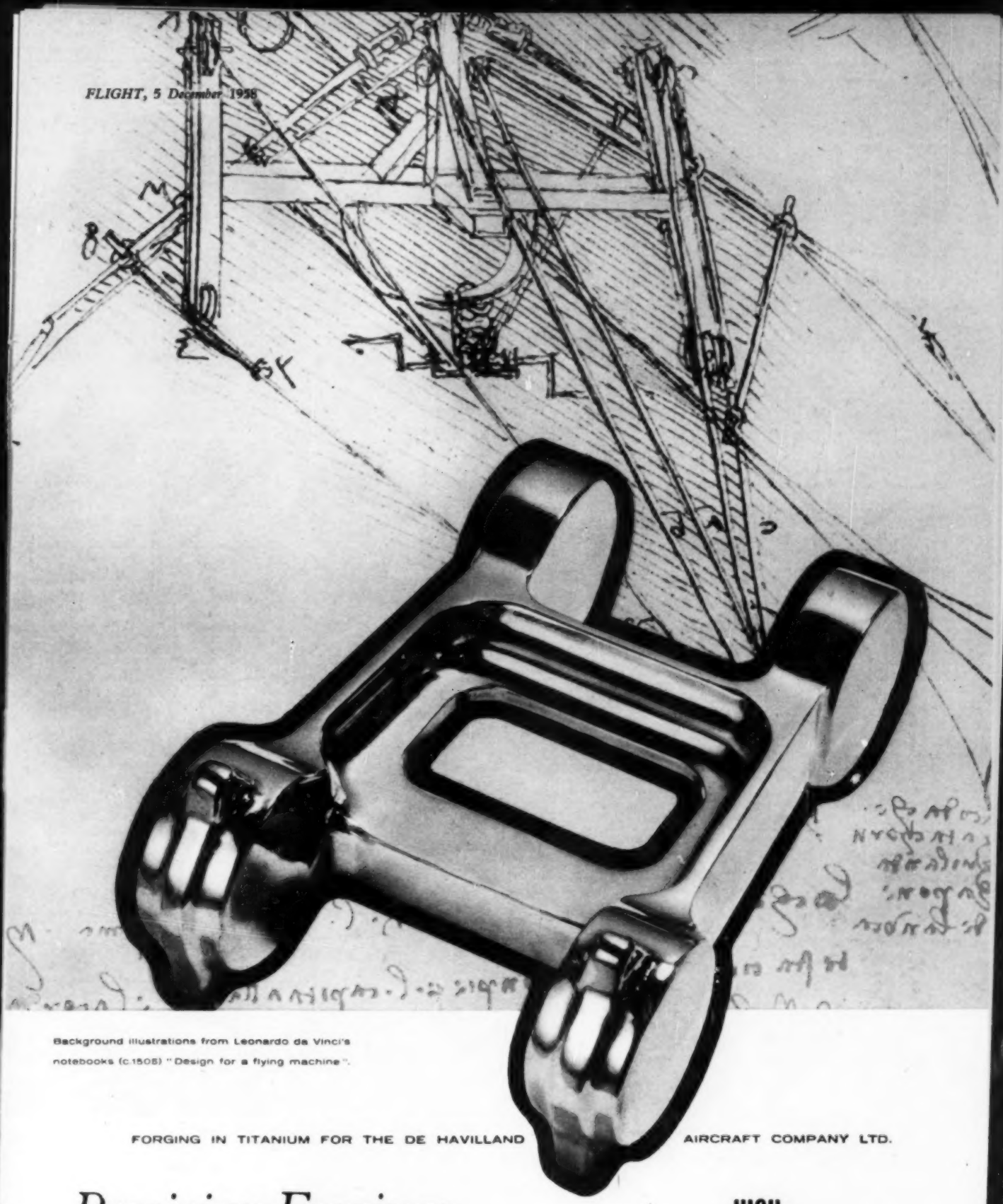
Along one of the upper edges of the launcher-erector are four lugs which contain the pivots to which the upper launching mount and transporter/erector are hinged. At the firing site, the launcher-erector's undercarriage is removed and the complete unit is bolted down to the concrete pad. The upper launching mount itself is then brought up and hoisted on top by a crane. Like its supporter, the upper part of the launcher is a precision-welded steel structure, and it arrives on an identical set of four pairs of wheels which are likewise removed. It is built up on a pyramid with an apex which will come directly under the centre of the Thor engine nozzle; the pyramid's function is to deflect the searing flame neatly so that minimum damage from heat and blast is caused to equipment on the pad. Around the periphery of this pyramid are disposed six towers, each some 10ft in height, hinged at their mid-points so that they may be pivoted towards or away from one another by internal hydraulic jacks. At the sides of the launcher are attachment faces for a service tower and the umbilical mast.

As its name implies, this mast provides a rigid support for the services which give life to the weapon's nose-cone and guidance up to the moment of firing. Some 60ft in length, the mast is a lattice structure which is normally brought to the firing site riding on an otherwise empty transporter/erector. A crane then hoists it on to its cantilevered attachment arm bolted to the side of the launcher. The mast is hinged so that its top may be hydraulically moved towards the missile, or, at the moment of launching, directly away from it.

When the pad is ready to receive its first round, it thus comprises the following units: the launcher-erector, rigidly fastened to the ground; the upper launching mount, hinged to the former; and the umbilical mast, hinged to its outrigger from the launcher. The loading of the missile then takes place according to the following sequence, which is illustrated by the sketches on pp. 866-7.

On arrival at the pad, the loaded transporter/erector is reversed up the inclined causeway to the launcher. Guided by the rear steersman on the inside of the curve, the ponderous vehicle is brought right up to the launcher until the latter is only a foot or so away. Then the tug is braked while the rear of the transporter/erector is raised by extending dolly wheels on either side, while the main road wheels are left on the ground. Jacking goes on until the pair of lugs on the projecting tail arms at the rear of the vehicle are level with the corresponding lugs on the launcher-erector; then the vehicle gently reverses until the two units are together; their union is ensured by a central locating wedge, and the transporter lugs are then clamped over their hinge pivots. Another pair of extending dollies on the transporter/erector are now brought into play. This time they are at the front of the articulated portion, and they are lowered until the two pairs of diminutive wheels which they carry are firmly on the ground. Then the 6×6 tug is released and drives away, its task completed.

Each of the six arms of the launcher is designed to bear its



Background illustrations from Leonardo da Vinci's notebooks (c.1508) "Design for a flying machine".

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share of the weight of the missile in the vertical position, much like pillars supporting an architectural dome. When the transporter/erector is hitched up to the launcher-erector, the base-plate of the Thor is brought almost into contact with the tops of these launcher arms (projecting horizontally, since the launcher is at this stage lying on its side). The hydraulic jacks in the arms open them to admit the rocket engine and then position them exactly in their correct positions around the base of the missile. Final location is ensured by spigots which are pushed up out of the ends of the arms into corresponding holes in the Thor. At the same time the missile is freed from the rear supports on the transporter/erector. The latter, together with the missile and the launching mount, is then free to pivot up into the vertical position on the launcher-erector hinges; nothing can come adrift, or out of precise alignment, since the whole assembly is hinged about the same axis. But still a great deal remains to be done while the missile is accessible in the horizontal position; for one thing, the payload has to be put on board.

Warheads, nose-cones and their accessories are stored well away from the firing pad. Assembly of the costly and deadly package precedes the arrival of the missile which will carry it, and an exhaustive programme of check-out and inspection follows, in the quiet of an air-conditioned and well-lit underground room. Then the nose-cone is hoisted on to its transporter, which is a four-wheeled vehicle by the Air Logistics Corp., carrying the cone upside-down in a jig which can be raised and lowered by a scissors-linkage. The transporter reaches the pad behind an ordinary tractor.

When the nose-cone transporter is brought up beneath the gaping nose of the missile it is carefully aligned until the cone is exactly in the correct place; all is then ready for the nose-cone transporter to be brought to life. This is done by an airman carrying a power-package like an outsize electric drill, behind which trails a thick cable. The package is clipped on to torque-bearing sockets and the drive-shaft causes the pantograph scissors-links to hoise the precious cone up to the level of the missile. The nose-cone jig rotates about lateral pivots and the complete unit is then moved home and secured by three latches. The scissors are lowered, the transporter drives away and the multi-pin plugs and hoses from the umbilical mast to the nose-cone are connected up.

Unless the missile is to be launched straight away, only minor work remains to be done for the time being. As an SM-75 requires a great deal of attention even when it is in storage, a shelter is provided to form a hangar over the launcher and thus improve both working conditions and serviceability. This shelter is a light metal building some hundred feet long, with a shape reminiscent of the traditional airship hanger—which, perhaps, is hardly surprising. The end of the shelter facing the causeway can slide to one side and the remainder of the building can be rolled away on rails under electric power to expose the complete launching area.

As already noted, a Thor squadron is reported to have fifteen rounds in launchers in the T-15 condition. At each of the fifteen launching sites the missiles will be snugly inside their shelters, except for any which may be taking part in a drill and training sequence. To fire a missile many operations must be performed, in a strict sequence and to the tight schedule of the count-down.

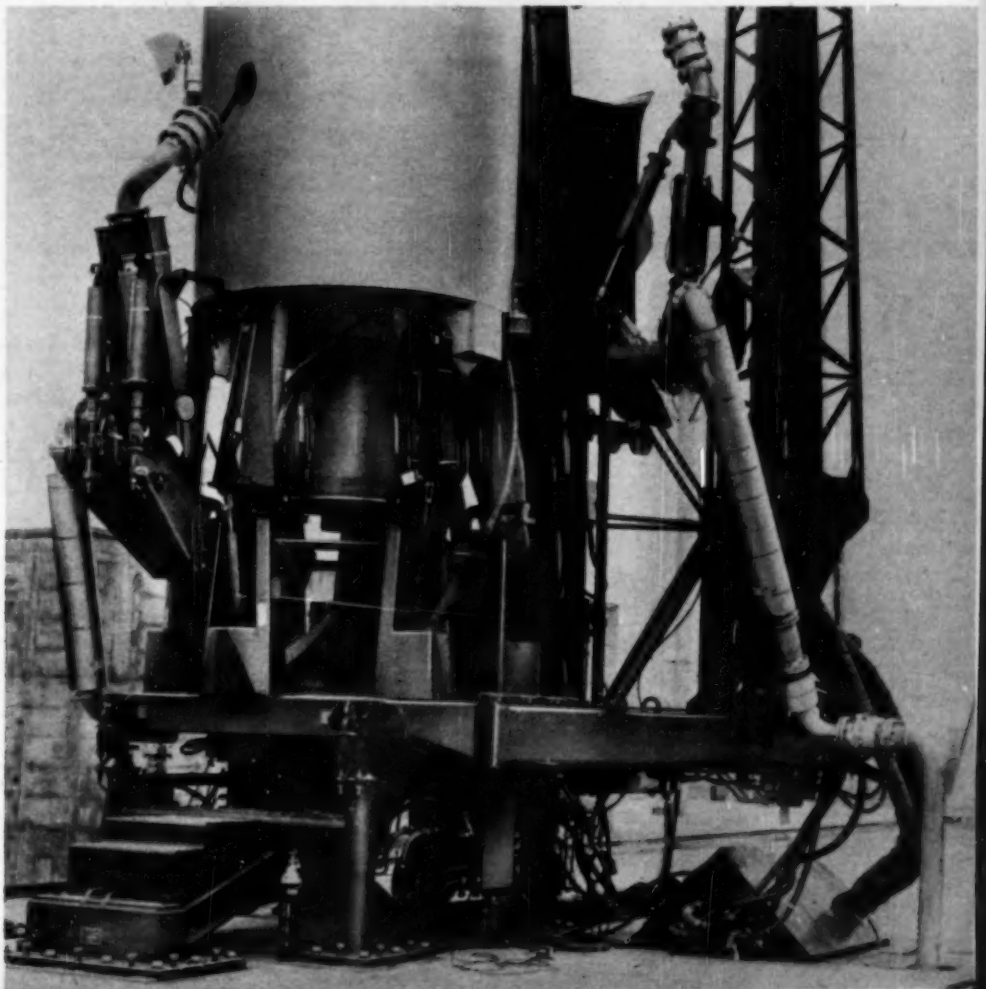
As might be expected, the resting missile does not have its tanks filled; no technique yet known can keep a liquid-oxygen tank in a missile reasonably topped-up for any length of time. The feed pipes from the propellant storage tanks at each of the sites are all connected up, however, and preparation for the passage of propellants to the missile begins immediately an alert is sounded. It is logical that this should be so, since fuelling is the factor determining the reaction time of the whole system.

As the drawing on pp. 870-871 shows, the propellants are stored above ground in long cylindrical tanks on either side of the launching pad. The smaller of the two is that for the RP-1 fuel. It has a capacity of some 8,000 Imp. gal and is connected to the missile via a valve and control point and thence along the main feed pipe, which is suspended above ground until the sloping bank at the side of the causeway is reached; the pipe then plunges underground beneath the shelter rails and emerges vertically through the shelter floor. At this point it is connected to a stack-pipe some 5ft high, from which a pivoting joint leads to the feed pipe which runs alongside the launcher and tilts through 90 deg with that assembly. Finally an inward-curving pipe leads to the quick-release pressure socket at the connection to the missile's own fuel system.

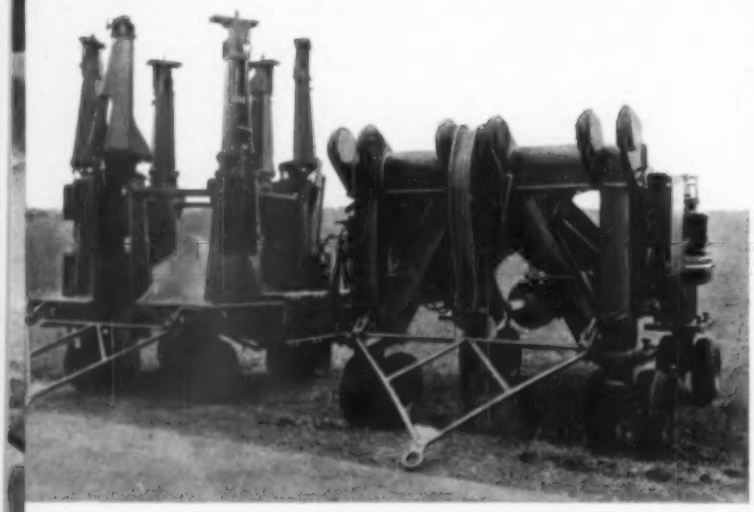
Passage of the fuel is effected by pressurizing the storage tank with gaseous nitrogen, which is carried in 38 high-pressure cylinders on an *ad hoc* truck. (Helium is used in the U.S.A., but this gas is a logistic problem in Europe.)

In the missile the fuel pours in at a rate of several hundred gallons per minute. Special anti-surge baffles restrain the turbulent fuel and prevent structural damage, just as they will in flight.

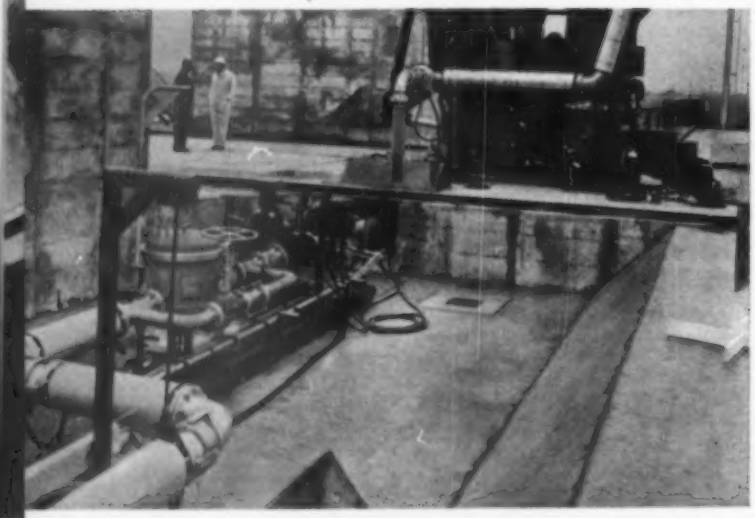
(Continued on page 872, after double page of Thor illustrations)



This photograph, taken at the first IRBM launch-emplacement to be constructed in Norfolk for Bomber Command, gives a clear indication of the launcher "hardware." The white-painted Thor can be seen standing on the six spigoted arms of its upper launching mount; before launching, the turbopump exhausts through a hole in the nearest arm on the left. Jutting off to the right is the support for the umbilical mast, the services to which issue from the prism-shaped box on the pad. To the left and right can be seen the main feeds for RP-1 and lox, the pressure-sockets for which are positioned by the prominent hydraulic jacks. The fire-extinguisher seems advisable

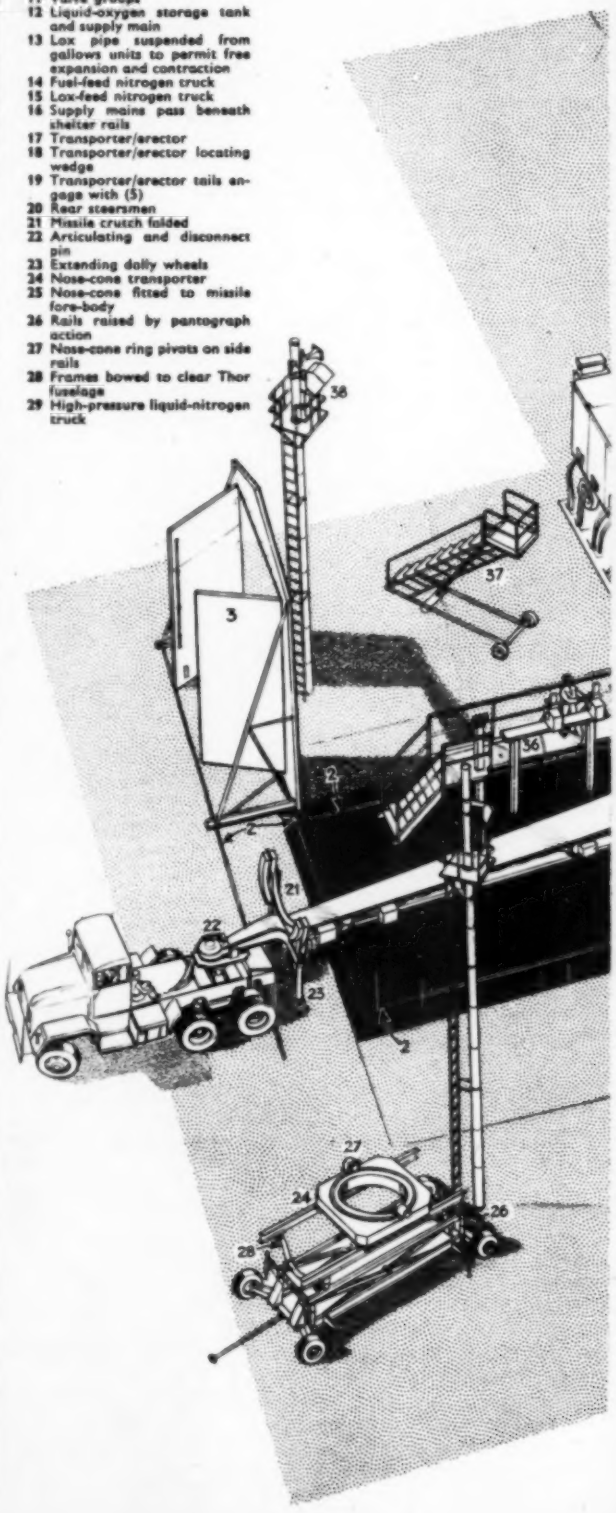


Here fitted with their undercarriages for transportation to the launching site are the upper launching mount (left) and launcher-erector (right)



Above is a close-up of the final portion of the fuel-feed circuit, in its concrete trench running up to the pad. Below, one of the R.A.F.'s first SM-75s is seen being erected during the contractor's check-out of the launcher; the portal (foreground) is that of the environmental shelter

1 Missile environmental shelter (moves farther back before launching)
2 Shelter rails
3 Shelter end-frame and doors
4 Launcher-erector
5 Upper launching mount
6 Launcher-erector ram
7 Umbilical mast
8 Pneumatic, electrical and instrumentation lines to guidance, nose-cone and warhead
9 RP-1 storage tank and supply main
10 RP-1 filter and de-watering system
11 Valve groups
12 Liquid-oxygen storage tank and supply main
13 Lox pipe suspended from gallows units to permit free expansion and contraction
14 Fuel-feed nitrogen truck
15 Lox-feed nitrogen truck
16 Supply mains pass beneath shelter rails
17 Transporter/erector
18 Transporter/erector locating wedge
19 Transporter/erector tails engage with (5)
20 Rear steersmen
21 Missile crutch folded
22 Articulating and disconnect pin
23 Extending dolly wheels
24 Nose-cone transporter
25 Nose-cone fitted to missile fore-body
26 Rails raised by pantograph action
27 Nose-cone ring pivots on side rails
28 Frames bowed to clear Thor fuselage
29 High-pressure liquid-nitrogen truck
30 Hydraulic/pneumatic trailer
31 Electrical equipment trailer
32 Electric power sub-station
33 Launching mount power-pack
34 Air-conditioning trailer
35 Vacuum-pump truck for lox storage
36 Short-range theodolite platform
37 Elevating service platform
38 Shadowless floodlight installation with public-address system
39 Blast revetments
40 Causeway



THOR...

This "Flight" drawing offers the most accurate and comprehensive illustration of a Thor launching complex that may at present be published. It will be noted that the pad itself is higher than the surrounding land, and it is reached by a sloping causeway. Our artist has included only the equipment actually required during a normal launching; the check-out trailers would normally be in the RIM building, and the launching-control trailer (which would probably govern three such complexes) would also be at a remote location. It must be stated that one concession has been made in this drawing. During a normal launching the transporter/erector would not be removed from the launcher once the missile was vertical, but it is shown here leaving behind its tug so that the launcher itself may be more clearly visible

FLIGHT COPYRIGHT

A. DOWDING

Meanwhile, the entire tankage and missile fuel system is purged with nitrogen to ensure that no explosive mixture or vapour can form anywhere. This inert gas is fed from a cart in which it is stored under such pressure that it remains in the liquid form.

As the correct rocket-worthy mixture of liquid oxygen, or lox, and RP-1 is in the approximate ratio of 3:2, the lox tank has to be larger than the fuel tank, both in the missile and on the ground. Moreover, unpressurized lox turns back into oxygen gas at any temperature above minus 183 deg C, and a tank for storing the lox under pressure—so that it could remain liquid at ambient temperature—would weigh many thousands of tons and present a somewhat unfair airlift problem. Accordingly the storage tank is made like a king-size Thermos flask. It is also the world's largest air-transportable storage vessel.

Made by the Cambridge Corp., in Lowell, Mass., each tank consists of two shells, one inside the other, both in the form of a cylinder with hemispherical ends. The inner shell is fabricated by precision-welding stainless-steel sheet. After assembly, the interior has to be cleaned by a special process, to keep the lox 99.995 per cent pure. The structure is that of a true monocoque, and the only stiffeners are circumferential rings. In order to minimize weight, the outer tank is made of aluminium, and great care is necessary in welding this material and preserving absolutely gas-tight seams. A high vacuum is maintained between the inner and outer shells to minimize the rate at which heat can flow into the lox from outside. Data for this remarkable tank include: length, over 50ft; height, 8ft; tare weight, 32,000 lb; capacity, 170,000 lb (11,242 Imp. gal).

Again, nitrogen pressure from bottles is used to expel the stored fluid out of the tank and into the missile. At once the outlet manifold glistens, and then acquires a thickening layer of frost. The expansion bellows in the fixed portions of rigid pipe creak and contract, and an even stranger thing happens to the main line leading to the firing pad. Supported by counterbalanced gallows units, the big pipe is normally straight along the ground; but when the lox starts flowing—at a low rate—it begins to cool the bottom of the pipe until, after a few minutes passing fluid at minus 183 deg C, differential expansion brings the main off the ground in a long arch.

While the colourless RP-1 and freezing, bluish lox roar into the Thor, buttons are pressed and the front of the shelter slides sideways. More buttons, and the shelter itself rumbles gently away until the entire launching area is open to the grey English sky. At once the launching crew prepare for the firing of their charge. Working to a strict sequence, and monitored from the launch control trailer, the major G.S.E. units, such as the power-distribution trailer (Food Machinery's powerpack), the hydro-pneumatic trailer, the electrical supply trailer and the main check-out trailer, are all brought into action. Everything that could be done before the alert came has been done; but still plenty remains.

Erecting the missile is the simplest, if the most spectacular, part of the launch cycle. The prime mover is a Cummins diesel, which drives the main generator feeding 1,000 kW into the launching complex. No reliance can be placed on a country's national grid system, and the entire base is considered self-sufficient in all such matters. The main electricity supply, which is by G.E., is then used to drive the main pump on the Food Machinery hydraulic powerpack trailer, which supplies hydraulic power to the pad. A switch feeds line-pressure to the main launcher-erector jack, and the launcher, umbilical mast, transporter/erector and missile move smoothly round the two big steel pins of their common hinge axis until, after about a minute, the blunt top of the Thor is pointing straight into the sky.

More buttons release the upper jaws of the transporter/erector, and the 65ft unit swings down again against the damping force of the ram until its forward feet are on the ground again. Then it has to be left alone; it cannot readily be got away from the launcher, and in any case its task is accomplished.

Nothing much then seems to happen, but in fact the tempo is increasing. The guidance system is checked by the short-range theodolite. Concentration increases as the count-down begins, and thousands of circuits, involving every portion of the missile, are subjected to programmed checks by the electrical equipment trailer. The main and supplementary checkout vehicles are not normally involved. Should a snag be spotted at any stage in the launching cycle, the checkout van can be plugged in at once, and the supplementary may be rushed round from the RIM building to make sure. Any repair is an immediate package-replacement job, and if it cannot be done in a few minutes the mission must be considered abortive.

Malfunctions, however, just should not occur, since their prevention is the prime task of the crew who minister to the beast while it lies in its shelter. This launching, at least, looks like being achieved on schedule, although something can always go wrong during the final count, and an American writer avers that the firing cycle can actually be stopped by a button in the launch-control trailer at T minus 0.5 sec.

The launch-control trailer comes increasingly into the picture as the final minutes tick by. Five minutes before firing, the pad is all but deserted. Fuelling has ceased, and only the lox continues to freeze its mains, and roar in a clammy cloud from the main missile vent. It is said that at T-2 even the lox has to call it a day; the missile tank has long since been full, and frost-encrusted, and topping-up (to make good the loss from the vent) has to stop some time.

Check-outs, and yet more check-outs, keep every possible trouble-area under surveillance. The elite crew in the launch-control trailer watch over 200 instruments and warning lights, and these are served by something approaching one thousand miles of wire on this chassis alone. But a mighty roar breaks through even into this select location; it comes from the twin verniers, and is far louder than their diminutive size would suggest. Only a few seconds more, and the main engine fires at zero.

It is all over in a few more seconds. The mighty chamber winds up to 150,000 lb thrust in a second or two, and as soon as it reaches a given minimum the launcher lets go. Off fly the multiple connections at the top of the umbilical mast, away swings the mast itself, and by this time the Thor is in the air. The mighty flame from the rocket and the gushing gouts from the turbopump exhaust light up the countryside, and the missile rises faster and faster. Soon it is above cloud, but its roar rumbles earthward for a long time.

Now there is nothing much left on the ground but a smoking, blistered launcher—bits of it glowing dull red—and a darkening of the special concrete around the pad. Men begin to appear again; some are still feverishly watching things in the launch-control trailer, but most can emerge from their warrens and listen to the sound of their departing vehicle. And, of course, they have a big psychological advantage over their predecessors in Bomber Command: they don't have to wait for anything to come back. At least, they ought not to.

W. T. G.

Departure of an XSM-75 Thor

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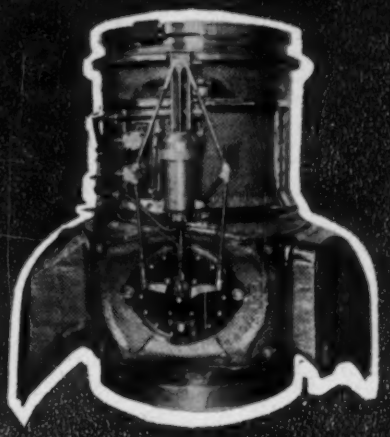
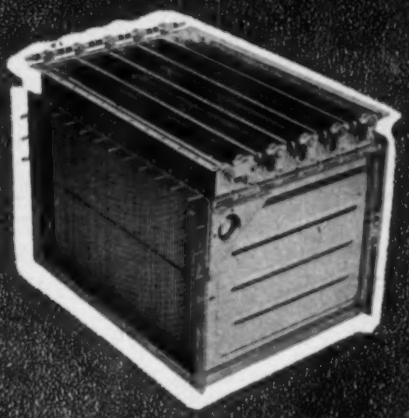


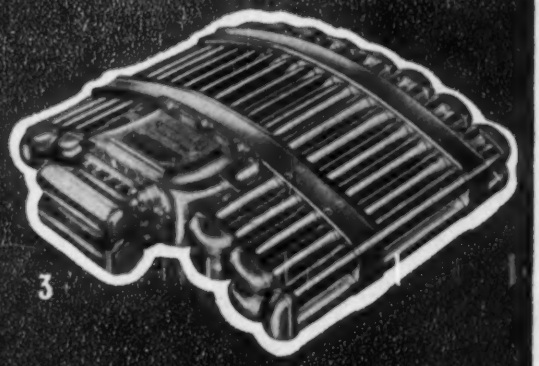
1

These thermal blankets are made of refractory fibre cased in .004 inch (.1016 mm) stainless steel. They are made-to-measure and are extremely light, the dimpled construction being responsible for their great strength. Specified for Rolls-Royce and Armstrong Siddeley jet and turbo-prop engines, these particular examples are shown fitted to the Rolls-Royce thrust reverser for the de Havilland Comet.



2

We design, manufacture and supply heat exchangers for many purposes in both aluminium alloy and stainless steel. This particular example is for the Vickers Vanguard's anti-icing system. Similar units are being supplied for the Fokker Friendship, the Bristol Britannia, the Armstrong Whitworth Argosy, the Vickers Viscount and the Handley Page Herald.



3

High pressure fuel-cooled oil cooler for high performance gas turbine engines. This unit is used in the Armstrong Siddeley Sapphire S.A.7.

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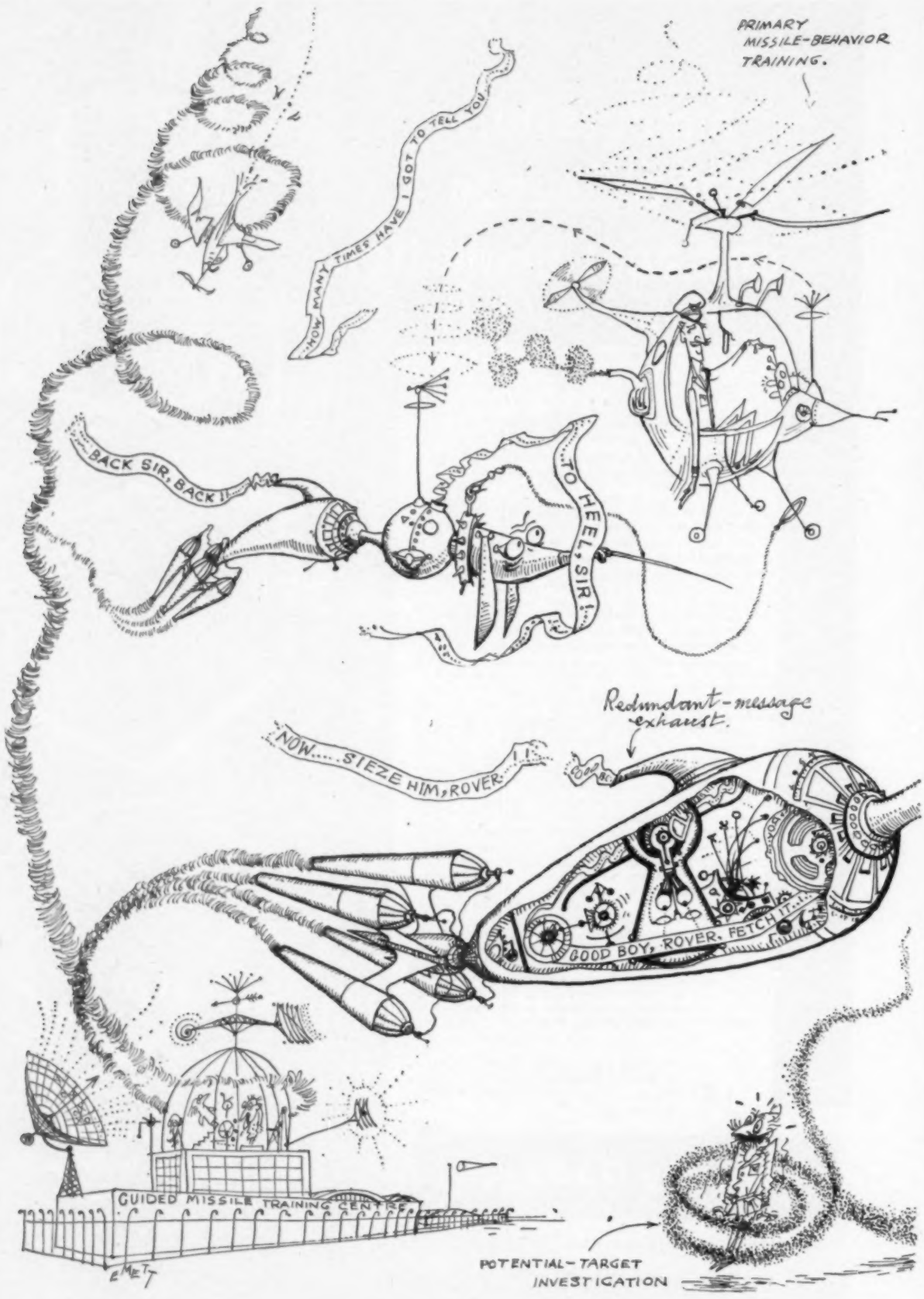
PRIMARY MISSILE-BEHAVIOR TRAINING.
HOW MANY TIMES HAVE I GOT TO TELL YOU
BACK SIR, BACK!
TO HEEL, SIR!
Redundant-message exhaust.
NOW... SIEZE HIM, ROVER!
GOOD BOY, ROVER. FETCH IT...
GUIDED MISSILE TRAINING CENTRE
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EMETT on Guided Missile Equipment

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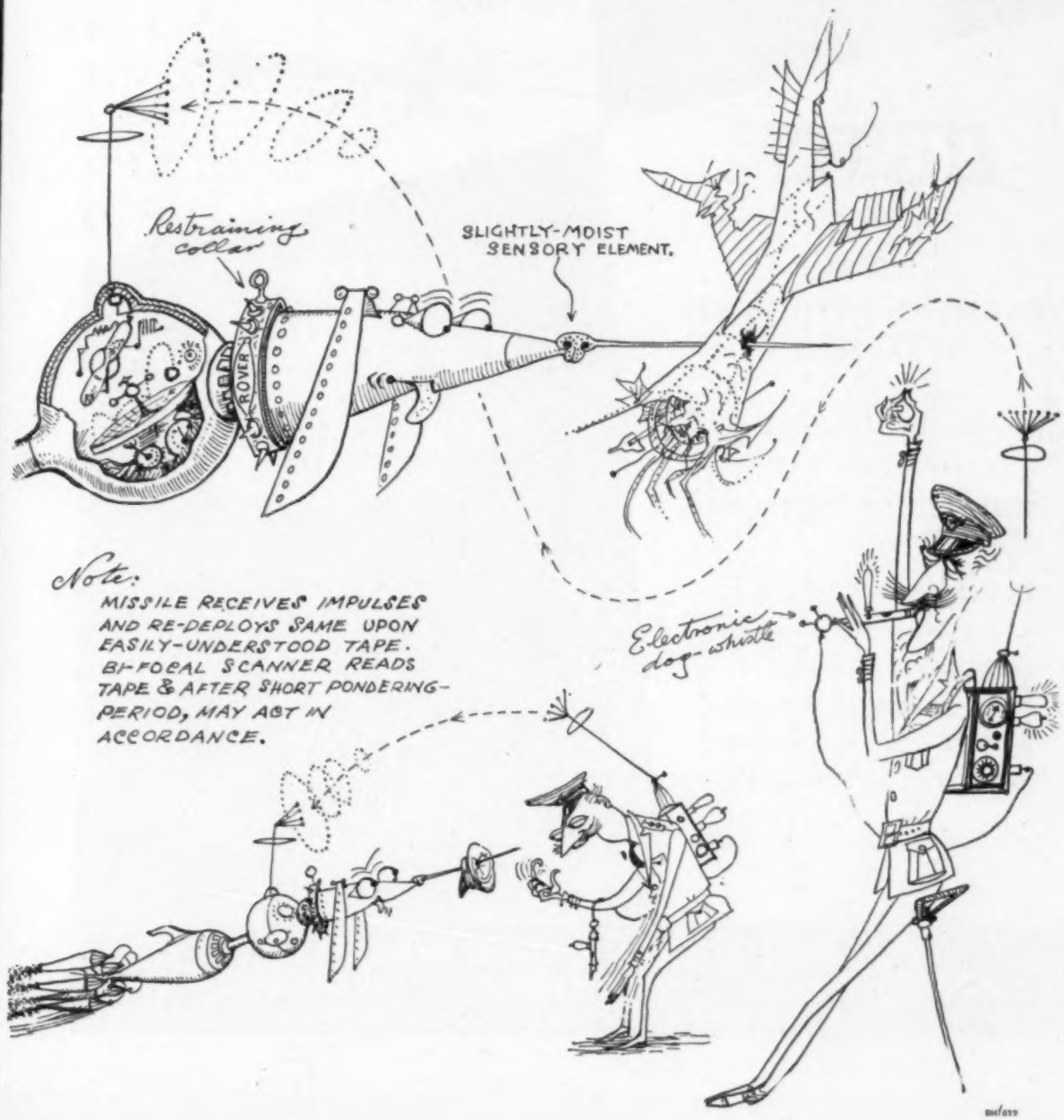
Restraining collar
SLIGHTLY-MOIST SENSORY ELEMENT.
ROVER
Note:
MISSILE RECEIVES IMPULSES AND RE-DEPLOYS SAME UPON EASILY-UNDERSTOOD TAPE. BI-FOCAL SCANNER READS TAPE & AFTER SHORT PONDERING-PERIOD, MAY ACT IN ACCORDANCE.
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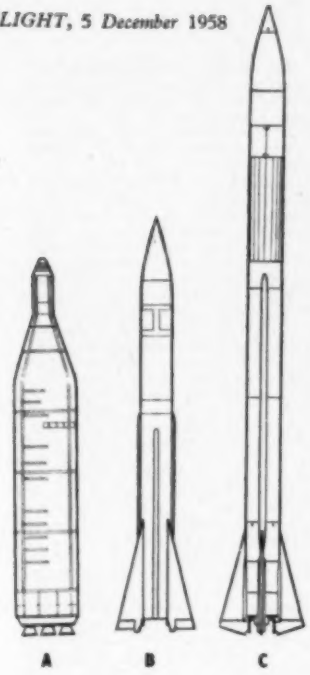


BELOW and on the following 25 pages will be found appraisals of the world's guided weapons—and a sprinkling of unguided missiles of particular interest. The text is as up-to-date, balanced and comprehensive as the writer—the Technical Editor—could make it. Many of the photographs have been chosen for their outstanding pictorial quality, and the line drawings have all been drawn during the past few weeks by Arthur Bowbeer.

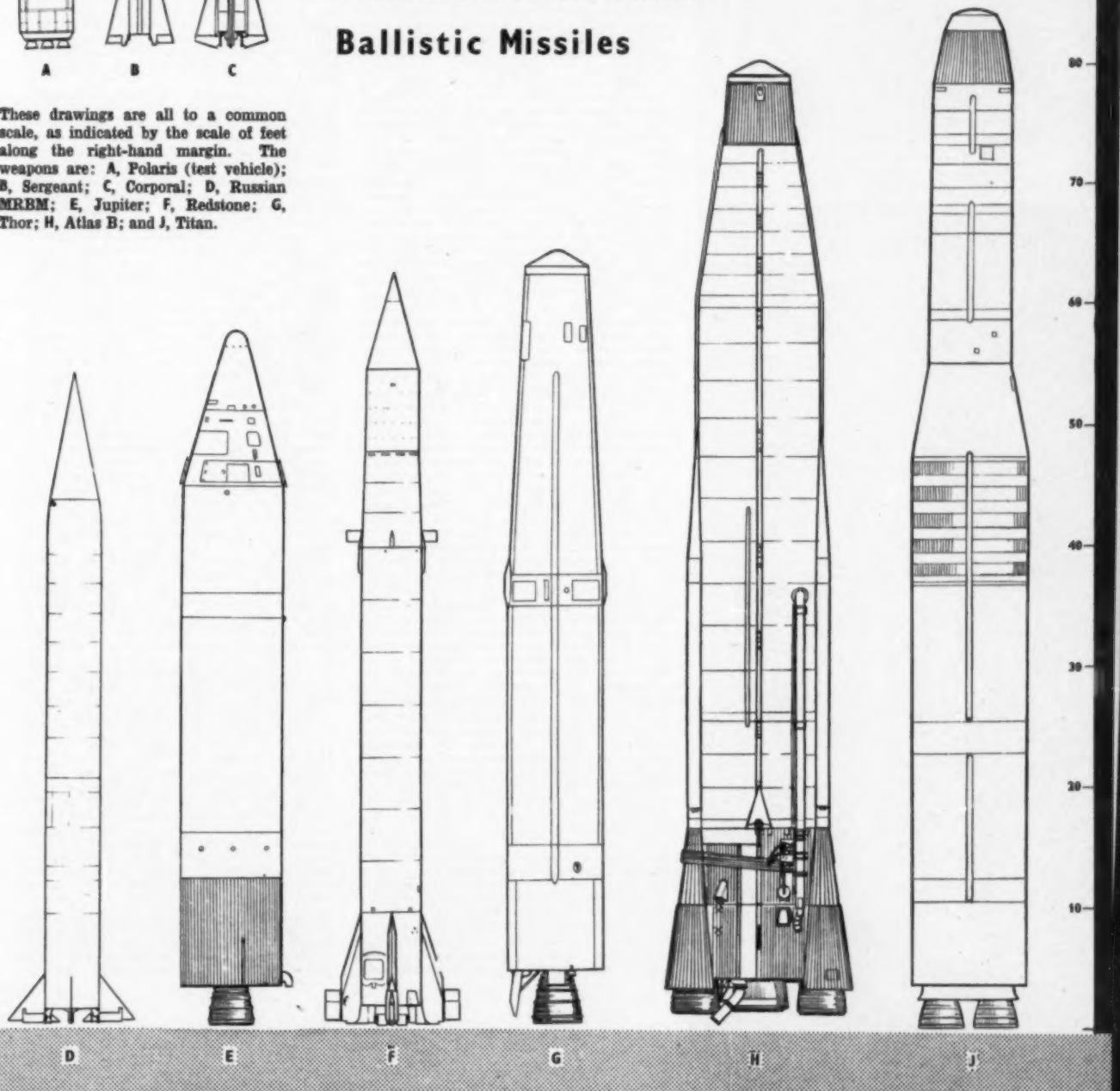
MISSILES 1958

The first section of this review is concerned with the mightiest missile family of all: the strategic ballistic missiles. They are arranged in alphabetical order of their name, or best-known designation—a system which has been followed throughout this survey.

SURFACE TO SURFACE

Ballistic Missiles

These drawings are all to a common scale, as indicated by the scale of feet along the right-hand margin. The weapons are: A, Polaris (test vehicle); B, Sergeant; C, Corporal; D, Russian MRBM; E, Jupiter; F, Redstone; G, Thor; H, Atlas B; and J, Titan.



ATLAS

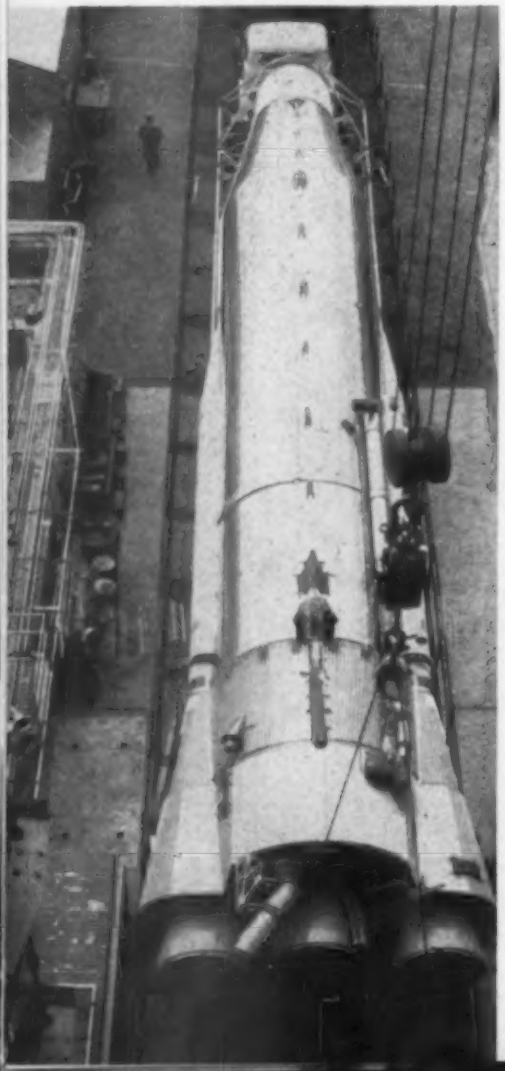
United States Air Force (Strategic Air Command) Weapon System 107A-1; the missile portion is Strategic Missile 65A.

Type: Intercontinental Ballistic Missile. Drawing: p. 873; photographs, p. 861 and below.

THE first ICBM to be developed outside the Soviet Union, the Atlas weapon system is scheduled to go into operational service with Strategic Air Command before the end of 1959. It is the outcome of a protracted history, which began with a research and development contract for a 5,000-nautical-mile ballistic missile assigned to the Convair Division of General Dynamics Corporation in 1946. At that time the state of the art was such that the project was little removed from the realms of fantasy, and it was shelved completely between 1947 and January 1951. In 1953, however, there came the "thermonuclear break-through," which drastically reduced the size of the warhead and increased the permissible miss-distance; the concept of an ICBM thereafter made sense, and the Atlas programme was placed on a "crash" basis the following year. Pilot production started at Convair's San Diego plant in 1955, and bulk production began last year in the new $40m facility of the company's Astronautics Division.

Atlas incorporates the following features, first developed for the Convair MX-774 test vehicle: stainless-steel airframe; thin-walled pressurized integral tankage; gimbal-mounted motors to provide control; and the use of vernier engines (as will be described). In addition, and in order to eliminate the difficult problem of high-altitude ignition, Atlas has only one set of tankage and both boost motors and the sustainer are fired on the ground.

Taken from the Atlas servicing tower at Cape Canaveral, this photograph shows the first Atlas B being backed on to its launcher before elevation to the vertical position. An Atlas B firing is depicted on p. 861



In the design of the airframe, Convair faced extremely severe problems. The body diameter is slightly greater than 10ft, the weight of propellants is enormous (approaching 100 tons) and airframe weight must be kept to a minimum, yet the skin has to be strong enough to withstand internal pressurization and stresses caused by axial and transverse acceleration and fuel sloshing, and must also withstand the intense vibration of rocket motors with an aggregate thrust of aproximately 400,000 lb. Most of the skinning is, in fact, formed from special stainless sheet produced by the U.S. Steel Corporation, which is hot-rolled between sheets of mild steel to produce thin-gauge panels measuring 90in × 230in. Extensive use is made of welding, and a light interior structure provides stability; the jettisonable skirt surrounding the boost package is stiffened by external corrugations.

Propulsion is provided by three main engines and two verniers, all produced by the Rocketdyne Division of North American Aviation at their Neosho plant, and burning a mixture of liquid oxygen and RP-1 hydrocarbon fuel. The boost package comprises a faired assembly containing two LR93-NA-1 motors with gimballed chambers. Each LR93 is attached directly beneath one of the lateral guidance packages, has a sea-level thrust of 165,000 lb and fires for about three minutes. Mounted on the axis of symmetry of the missile is the sustainer, which is an LR105-NA-1 gimbal-mounted engine with a sea-level thrust of 60,000 lb (54,000 lb in the first batch).

In Atlasses so far launched each engine has its own turbopump, but later rounds will have a single gas generator and turbopump for all three. The tanks are pressurized by helium carried in numerous spheres, of from 16 to 24in diameter, which are now made of titanium alloy; reducing valves cut the storage pressure from 3,200 lb/sq in to a much lower value before feeding into the main tankage. Dumping valves empty the airframe of any fuel remaining after the final burn-out. Each of the verniers is gimbal-mounted for roll stabilization, and also controls precision thrust-adjustments and final cut-off. As the verniers are outrigged on pylons attached to the sides of the body they are protected against aerodynamic heating by phenolic-resin fairings.

When Atlas was being designed it was far from certain that an inertial guidance system could be made to work in time. Accordingly the guidance is virtually of the radio-command type—although it is described as radio-inertial. Such a system prevents any firing in salvo without duplication of the ground equipment, yet it is believed that its accuracy is better than that so far achieved by pure inertial missiles. The powerful and extensive ground equipment includes a doppler radar with a base leg which may approach a mile in length, together with cupola-mounted pulse radars for tracking purposes, all this equipment being produced by General Electric's Heavy Military Electronic Equipment Department at Syracuse.

An airborne transponder has to be carried in order to increase the return signal-strength at extreme range and to combat the ionization by the great exhaust flames. With its help, the ground radar produces precise and immediate information on azimuth and elevation, slant range, vertical and lateral velocity and acceleration. This data is converted by a large transistorized digital computer—a product of the Burroughs Corporation—into a continuous indication of the precise point of impact, which is then compared with that desired. In theory the system can be jammed; nevertheless, G.E. and the University of Chicago have so far been unable to impair guidance, and even the theoretical jamming pre-supposes line of sight to the launching base. An indication of the magnitude of the guidance problem is provided by the contracts for the principal supplier, which so far amount to $83m for G.E. and $45m for Burroughs.

General Electric are also responsible for the nose-cone, which is produced by the Missile and Ordnance Systems Division at Philadelphia. The Mk 1 cone is very blunt and is described in greater detail in the feature article on Thor elsewhere in this issue. Owing to the large size of the Atlas warhead, which has a yield reported to be three megatons, there has to be a re-entry body behind the cone, and this comprises a slightly tapering cylinder with an externally corrugated skin of heat-resistant steel. The complete assembly, major structural parts of which are produced by Republic Aviation, separates from the missile at the transition ring shortly after vernier shut-down. Warhead fuzing and arming is accomplished by a typical Sandia sytem.

Atlas is transported on a low-lying steel-tube vehicle produced by Goodyear at Phoenix, and a pressurization system keeps the missile body inflated en route. Static testing has been centred at Sycamore Canyon, where one missile remained in the stand for eight months producing data equivalent to ten complete missions. Test flights have so far been conducted entirely at the Air Force Missile Test Center at Cape Canaveral. The missile and transporter are hoisted into the vertical position by a winch mounted in the 100ft gantry, which, although it is designed for 120-knot winds, can be rolled some 400ft from the pad before firing. The launcher at Cape Canaveral is a welded-steel assembly weighing 62,000 lb. Two large jaws, which grip the missile to maintain stability in high winds, are opened at the moment of launching; mechanisms within the launcher weigh the missile and its propellants, and measure the thrust, engine gimballing and misalignments. Count-downs in the past have averaged four hours or more, but operationally it is expected that the complete fuelling sequence and check-out will take approximately two hours. In the Canaveral installation storage is provided for 13,323 Imp. gal of RP-1 and 24,980 Imp. gal of liquid oxygen; these propellants are fed at 1,000 gal/min by a 5,000 lb/sq in helium system. Liquid nitrogen is used for purging.

Strenuous efforts put the first Atlas on the pad in the spring of 1957. This was a Model A, with boost and vernier power only and a dummy nose-cone. All Model As had a range of approximately 600 miles. The first round was fired on June 11, and after a smooth launching and stable climb, uncontrolled gimballing caused pitch-over and eventual structural failure, necessitating destruction by the range safety officer. A similar fate was suffered by round No. 2 (September 25, 1957), but successful flights followed on December 17 and January 10. The Model As fired on February 7 and February 20 lost directional stability and broke up shortly before the burn-out point; after these malfunctions were isolated good missions were achieved on April 5 and June 3.

The first Atlas B with the sustainer engine and separable Mk 1 nose-cone reached the pad in the summer of this year. A control-system failure caused this first three-engined Atlas to break up in flight on July 19. The second was launched successfully on August 2, attaining a speed of more than 15,000 m.p.h., a height of several hundred miles and a range of more than 2,500 miles (the full propulsion system was employed, together with a mass-ratio equivalent to the full design range, but the great overload of instrumentation resulted in a substantial curtailment of actual range). A third B model was completely successful on August 28. Full-range firing of operational-type rounds is to start shortly.

Atlas is scheduled to achieve IOC (initial operational capability) in one year's time. WS-107A-1 complexes are being constructed at four bases: Cook A.F.B. (Lompoc, Cal.) is well advanced, Francis E. Warren A.F.B. (Cheyenne, Wyo.) should have four pads operational by next September, and Offutt A.F.B. (Omaha, Neb.) and Fairchild A.F.B. (Spokane, Wash.) are in an early stage. The first ballistic missile division of S.A.C. has headquarters at Cook A.F.B. Logistic administration is centred at Norton A.F.B. (San Bernadino, Cal.).

S.A.C. squadrons with fifteen Atlas will each represent an outlay of $57-60m. A bare SM-65 airframe and propulsion system is expected to cost approximately $1.5m in production; the warhead will probably cost a similar amount. In January Convair received an initial letter-contract of $145m for design, fabrication and testing, and this was supplemented by a further contract in July for $314.8m. The present schedule calls for 130 ICBMs (including a few Titans) to be on S.A.C. pads by the end of 1961.

SM-65A Atlas: Body length, approximately 79ft; tankage diameter, 10ft; launching weight, 240,000/243,000 lb; aggregate sea-level thrust, 390,000 lb; re-entry speed of nose-cone, 15,000 m.p.h.; design range, 5,500 n.m. (6,333 statute miles).

BLUE STREAK

Royal Air Force Bomber Command (Strategic Missile Squadrons).

Type: Long-range ballistic missile. No illustration permitted.

BLUE STREAK is the code-name for the first British ballistic missile. It is officially classed as a "long-range ballistic missile" or LRBM, and unofficial reports have averred that its design range is 2,500 nautical miles (2,879 statute miles). The reference to it in the 1958 *White Paper on Defence* stated "a . . . ballistic rocket of a more advanced type is being developed in close co-operation with the United States . . . It is being designed for launching from underground." On May 2 the following text was issued by the prime contractor, de Havilland Propellers, Ltd.:

"In August 1957 the Minister of Defence revealed that Great Britain was engaged on the design and construction of an intermediate-range ballistic missile. de Havilland Propellers, Ltd., announce that they are the prime contractors and the co-ordinating authority for this work, with Rolls-Royce, Ltd., the de Havilland Aircraft Company, Ltd., and the Sperry Gyroscope Company, Ltd., as associated main contractors.

"This ground-launched weapon will carry a thermo-nuclear warhead with extreme accuracy over a range of several thousand miles to a surface target.

"Extensive facilities for the initial testing of the various components and systems are being established at a number of centres in the United Kingdom. One of these is at the headquarters of de Havilland Propellers at Hatfield, in Hertfordshire, where large steel towers have already attracted attention. Another site, to be managed by Rolls-Royce, is being built at Spadeadam Waste, in Cumberland, where test work on the rocket motors will be carried out. Firing trials of the complete weapon will take place on the extended rocket range at Woomera, in Australia.

"The teams in each of the companies engaged in this project are well prepared and equipped to carry the high responsibility entrusted to them, and work proceeds with confidence in the success of what may justifiably be called the ultimate defence system of this country . . ."

It is evident that the prime contractor will act as system manager, that Rolls-Royce will manage the propulsion, D.H. Aircraft the airframe and Sperry the guidance. An unofficial report has suggested that steel will be the principal airframe structural material, and this is borne out by the finish of the main body section mounted in a vertical test frame at Hatfield. Rolls-Royce have a licence-agreement with the Rocketdyne Division of North American Aviation, and one may expect portions of the Blue Streak motor—in particular the chamber—to be based upon Rocketdyne (liquid-propellant?) experience. In fact the later design of the British vehicle and its warhead should enable an engine of Thor/Jupiter thrust to confer a range of the order claimed. It is particularly worth noting the adoption of the "hard pad" concept, i.e., underground launching. This presupposes a complete lack of mobility but renders the site less vulnerable to attack by any normal weapons. It is not yet known, of course, whether Blue Streak's sustainer will be fired at the bottom of the launching well, or whether the weapon will be raised before firing by compressed air or hydraulic means.

Blue Streak: length, probably about 60ft; diameter, approximately 10ft; propulsion, probably by a gimbal-chamber Rolls-Royce sustainer of at least 150,000 lb thrust, and one or more Armstrong Siddeley PR.23 verniers, each of 500 lb thrust; launching weight, probably not more than 100,000 lb; design range, reported to be 2,500 n.m. (2,879 statute miles).

CORPORAL

United States Army and British Army.

Type: Ballistic missile for battlefield use. Drawing: p. 873.

URGENTLY evolved during 1951-2 from a research vehicle called Corporal E, this slender missile has been in service with the U.S. Army for four years and with the British Army for two. A history was published on p. 904 of our 1956 review issue. Corporal is made by Firestone, with radar doppler/tracking/computing guidance by Gilfillan and a 20,000 lb-thrust acid-aniline motor by Ryan. A large high-explosive or kiloton nuclear warhead can be carried. In a demonstration at White Sands Proving Ground last July a Corporal was fired against a target 31 miles from the launcher: it impacted 48ft to the left and 12ft short.

M4 (SSM-A-17) Corporal: length, 46ft; diameter, 30in; fin span, 84in; launching weight, 12,000 lb; burn-out speed, about Mach 3.5; maximum range, 70 to nearly 100 miles, depending on warhead.

JUPITER

United States Air Force (Strategic Air Command) and possibly at least one NATO Air Force; missile portion is Strategic Missile 78.

Type: Intermediate-range ballistic missile. Drawing: p. 873; photograph, p. 876.

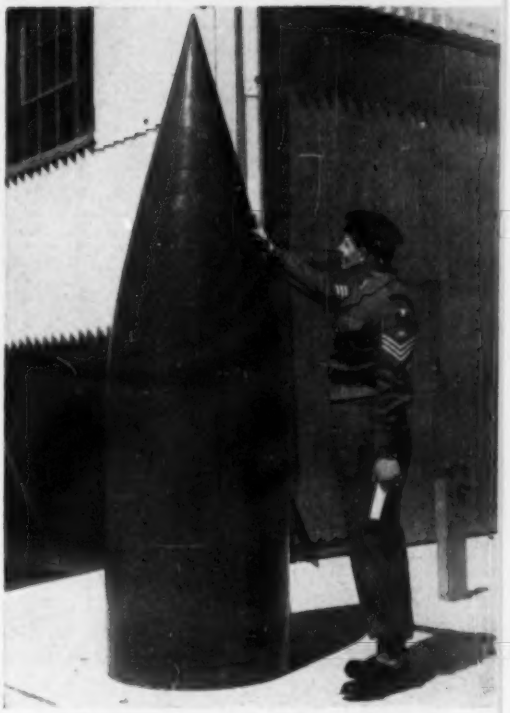
UNDER the terms of the Wilson Memorandum of November 1957, the U.S. Army were forbidden to develop or operate any weapons with a greater range than 200 statute miles. Accordingly the Jupiter IRBM, which was then in an advanced state of development, was turned over to the U.S. Air Force (although subsequent technical development of the Jupiter weapon system has, in fact, remained under Army authority). The U.S.A.F. maintain a Jupiter liaison office at the Army Ballistic Missile Agency at Huntsville, Ala., and Strategic Air Command personnel have been attending training courses at the same Army establishment.

Development of Jupiter began in mid-1955. For more than a year it was hoped that the eventual missile would also prove acceptable to the U.S. Navy for shipboard use. Partly on account of this, the airframe was designed to a relatively low fineness ratio, the tankage section having a constant diameter of 105in. Most of the airframe is manufactured from high-strength aluminium alloys, and integral tankage is employed to reduce weight and increase fuel capacity. Welding is extensively used and the welders at the Army Michigan Missile Plant operated by Chrysler—where production Jupiters are built—have had to requalify to a new and more stringent specification for work on this weapon. The tankage is assembled from eight 25ft panels, which are extruded to provide integral stiffening and chemically milled to the desired thickness. External corrugations stiffen the relatively unstressed skirt beneath the tankage which provides a fairing around the rocket motor.

The latter is an S-3 gimbal-chamber engine produced at Neosho, Mo., by the Rocketdyne Division of North American Aviation. The complete unit is almost identical to the LR79 used in Thor, and has a similar sea-level rating of 150,000 lb thrust. The propellants are liquid oxygen and RP-1, and they are fed to the chamber mounted beneath the liquid oxygen tank. The fuel lines pass within the liquid oxygen tank, there being no external feed pipes or cables whatever—a remarkable achievement. The main body of the missile has no vernier. Instead, the turbopump gas-generator exhaust is piped to a nozzle at the periphery of the base of the weapon, and hydraulic actuators can pivot this nozzle through an arc of ± 90 deg in order to provide roll control. This system is ingenious and economical, and has been found to work quite adequately in practice.

Unlike the ballistic missiles of the Air Force, the Jupiter nose-cone is not of the blunt heat-sink type. Instead, the fore-body has a conical form which tapers to a final nose radius of less than 12in. The included angle is no more than 27 deg, and the complete assembly—which is fabricated by Goodyear at Akron—is covered with layers of ablating plastic, i.e. layers which are designed to burn off uniformly as the nose-cone re-enters the atmosphere. Multiple laminations of organic material are employed, the outermost being a phenolic resin by the Cincinnati Research and Test Laboratory. Ablation starts at about 800 deg F. It is worth noting that, in spite of the relatively small budget available, this Army nose-cone was the first in the western world actually to achieve re-entry, and a similar principle is likely to be adopted by the U.S. Air Force in future models of ballistic weapons.

Near the tip of the nose-cone is the warhead, which is a development of that carried by the Redstone and has a yield of approximately one megaton. The device itself is produced by the Atomic Energy Commission, and the systems for fuzing and arming are products of Picatinny Arsenal. Behind the warhead is a transverse bulkhead, in the centre of which is a small solid-propellant rocket motor produced by Thiokol. After burn-out of the main sustainer the nose-cone separates. Thereafter, the small solid rocket provides vernier propulsion for up to 45 sec, and is finally cut off when the nose-cone velocity is within 1ft/sec of the desired value. Then the warhead itself separates gently, leaving the guidance package and vernier in the larger rear portion of the nose-cone.



Although one of the slimmest ballistic missiles, Corporal can carry a substantial warhead. A typical 30in nose is here being examined by a sergeant of the Royal Artillery

Guidance is of the pure inertial variety, and the airborne system is essentially a refined version of the highly developed equipment used in Redstone. Both systems are being produced along parallel assembly lines at the Long Island City plant of the Ford Instrument Company, Division of Sperry Rand Corporation. Engineering and manufacturing assistance is being provided by the Farragut and Sperry Gyroscope Divisions of the same Corporation. Both the stabilizing gyros and the integrating gyro accelerometers incorporate air bearings, in contrast to the liquid-floating rotors of the U.S.A.F. inertial-quality gyros. A Leonard regulator is employed to maintain the pressure of the air-bearing supply within the limits of ± 0.2 lb/sq in.

Unlike Thor, the stabilizing platform is gimballed from the inside out, i.e., the gimbal rings are built progressively outwards from a fixed hub, in contrast to the conventional pattern in which the stabilization gyros and accelerometers are mounted at the centre of a gimbal assembly pivoted at the periphery of the outermost ring. It is worth noting that the Jupiter guidance system is reported to weigh much less than that of the Air-Force-developed units, and a weight between 250 and 300 lb has been unofficially quoted. In comparison with Redstone, the gyros used in Jupiter are miniaturized; similar patterns have worked very well in U.S. Army satellite and lunar probe vehicles.

The basic development, and the manufacture of prototypes, was handled entirely by the Army Ballistic Missile Agency at Huntsville, with the technical assistance of the Jet Propulsion Laboratory of the California Institute of Technology. Production has been assigned to the Chrysler Corporation, who maintain plants at Van Dyke Road, Detroit; Warren, Mich.; and Sterling Township, for ballistic-missile airframe manufacture and final assembly. Jupiter production began at Chrysler in

Developed by the U.S. Army for operation by Strategic Air Command of the U.S.A.F., the SM-78 Jupiter has several times "flown the design range, impacted in the designated area and permitted recovery of the nose-cone." This photograph was taken at Cape Canaveral shortly before the successful flight on July 17 of this year

MISSILES 1958...

November 1957, and is currently running at the rate of about five rounds monthly. So far this year research, development, product-improvement and manufacture of airframes, spares and support equipment by Chrysler have absorbed funds totalling approximately $125m. Sub-contractors include General Mills and the new Sperry Microwave Electronics Company, both of whom make ground support equipment, and Fruehauf (transporter), Watertown Arsenal (launcher) and Gamm Trailer Corporation (electronic check-out truck).

Every portion of the system is mobile, and the Army at least did not envisage Jupiter being fired from permanent fixed sites. The steel-tube trailer is towed by a 6×6 truck, the missile being carried complete with warhead and motor, and being lifted on and off by a crane. Cables and winches are then used in conjunction with an A-frame to hoist the missile into the vertical position on its simple launcher. The latter is not hinged like that of Thor, and thus all rounds on launchers remain in the vertical position exposed to the elements. For operation away from friendly industry, Air Products supply lox generating plant, also mobile, with a capacity of 20 short tons per day.

In Strategic Air Command service each squadron will be equipped with fifteen SM-78s. Six of these will be ready on their launchers in the T minus 15 condition (i.e., these six rounds could be fired on the 15th minute from the order being given). Six more would be constantly in a state of readiness and the remaining three would be unavailable for reasons of unserviceability or routine checking. This follows the basic Army concept of mobile operations in possibly unfriendly territory. Compared with the Thor system, there is rather more manual work to be done, and total personnel for each squadron will be about 650. Should the U.S.A.F. retain Jupiter, a revised weapon system may be evolved, with a greater number of launchers per squadron and a correspondingly reduced reaction time.

Neither of the first two Jupiters achieved a successful flight, but the third round (incorporating anti-slosh tankage baffles and fired in May 1957) achieved the design range of 1,500 nautical miles under the control of the production guidance system. In August 1957 a major technological hurdle was surmounted by the recovery of a scale model of the ablating nose-cone. At 1 a.m. on May 18 of this year a representative production Jupiter was fired from Cape Canaveral, achieving in the course of a 15-minute flight the full design range to a position north-east of Antigua. From 50 miles away, two ships with extensive instrumentation plotted the re-entry of the nose-cone, instrument package and main body. This Jupiter first became visible as a point of light at a height of 200,000ft travelling at 9,000 m.p.h. After three seconds the three units were seen to separate, and the burn-out of the instrument package and booster produced radiation intense enough to illuminate large clouds and the ships at the distance of almost 50 miles. Another completely successful full-range mission and nose-cone recovery took place on July 17, and a third on August 27. During July the Secretary of the Army, Wilbur Brucker, stated that 38 Jupiters had then been fired, 29 being completely successful and seven partially so.

On January 15 of this year the 864th Strategic Missile Squadron of Strategic Air Command was activated at the Army Ballistic Missile Agency, the Army Ordnance Guided Missile School at Huntsville being assigned the task of training the Air Force squadrons. The 864th completed their training two months ago and have now been succeeded by the 865th. It is expected that the first Jupiter squadron will be deployed overseas—almost certainly in Italy—at an early date. As things stand at present, both Jupiter and Thor remain in production, but the American aeronautical Press, not quite disinterested, have consistently forecast that the Army-developed weapon will be relegated to a space-flight rôle after two or three squadrons have been equipped. Whether or not this viewpoint is justified remains to be seen.

SM-78 Jupiter: length, 59ft; diameter, 105in; launching weight, 105,000 lb; sea-level thrust, 150,000 lb; re-entry speed of nose-cone, up to 10,000 m.p.h.; design range, 1,500 n.m. (1,727 statute miles).

MINUTEMAN

United States Air Force (Strategic Air Command); the missile portion of this weapon system will be designated XSM-80.

Type: Second-generation ballistic missile.

MINUTEMAN is to be the U.S.A.F's second-generation strategic ballistic missile system, replacing all the first-generation weapons. Minuteman will be smaller, lighter, cheaper and more effective than its predecessors and will have much-reduced reaction time and vulnerability. The vehicle will consist of three separate stages which can be used individually or together to produce an MRBM, an IRBM or an ICBM. During the past year the U.S. Air Force has publicly admitted that "there must be a better way of doing things" than by following the procedures adopted for the first generation, and Minuteman sets the pattern for the future.

In February the project was placed on a "crash" basis by the U.S.A.F. Ballistic Missile Division at Inglewood, and although the project was stated to be "planned for austerity," the appropriation for the fiscal year 1959 apparently amounts to $140m (50m+90m).

The third stage is to be about 10ft long. No information is yet available regarding the nose-cone, but it has been unofficially stated that the yield of the normal warhead will be comparable with that of Titan when firing against first-priority targets, although it will be smaller and cheaper. Third-stage propulsion will comprise an Aerojet-General solid-propellant motor, with Thiokol providing a stand-by engine and Hercules Powder Company conducting a study into the use of a double-base propellant (possibly ammonium perchlorate). The second stage will be 15ft in length, with solid propulsion either by Aerojet-General or Thiokol (equal partners on two separate engines). With this stage added the vehicle becomes an IRBM. The first stage is to be a thin-walled cylinder 30ft in length, containing solid propulsion by Thiokol with "limited back-up" by Aerojet-General. Each stage is expected to have either a single fixed nozzle with deflectors or a single swivelling nozzle (never before achieved on solid motors of this size).

Guidance will be pure-inertial by the Autonetics Division of North American Aviation, the nose-cone is being developed by Avco and transporters will be by Beech Aircraft. Chief contractor, in charge of assembly and testing of the entire weapon system, will be the Boeing Airplane Company. According to *Missiles and Rockets*, the assembly line will be laid out by next February (at Seattle) and it is hoped that user squadrons can be equipped by 1962. Altogether the Minuteman system is the outcome of millions of man-hours and study into what situations could arise in a future conflict of any description. The complete system is being so designed as to be capable of readily incorporating any new technological developments for a period of at least ten years. The cost per missile is expected to be between 10 and 14 per cent of that of the first-generation ICBMs. Its detail design and relatively diminutive size are such as to facilitate the construction of sunken silo bases, where the various types of SM-80 would be serviced by automatic systems and have an indefinite shelf life.

XSM-80 Minuteman (estimated): overall length of three stages (as ICBM), 55ft; body diameter of first stage, about 84in; launching weight (as ICBM), probably less than 80,000 lb; design range (as ICBM), 5,500 n.m. (6,333 statute miles).

PERSHING

United States Army.

Type: Medium-range ballistic missile for Army use.

DURING the three years since the Wilson Memorandum forbade the U.S. Army to develop vehicles with a range greater than 200 miles, many have felt that this restriction should be removed. Earlier this year Mr. Wilson's successor as Defense Secretary, Neil McElroy, removed the 200-mile limit and permitted the U.S. Army officially to continue a programme for an MRBM to replace Redstone. Every modern technique was to be employed, including a miniaturized warhead, a solid sustainer of high specific impulse, and light-weight ground support equipment to produce a weapon system with high cross-country mobility and complete air transportability. The design range is 500 miles; but it has been suggested that future advances in the state of the art could enable this range to be substantially increased in the future, and the Secretary of the Army, Wilbur Brucker, is reported to consider 1,500 nautical miles (the IRBM bracket) as within Army tactical requirements.

The name of the MRBM is Pershing, and the weapon-system manager is the Orlando plant of The Martin Company. Test vehicles, incorporating the long-established LEV-3 gyros, have so far been some 30ft in length and only 24in in diameter. This slenderness suggests incorporation of Vanguard (satellite vehicle) experience; one would hardly imagine that the operational weapon could be so slim. The test vehicles, at least, are reported to be two-staged, the second stage separating at about 40,000ft and being recoverable. Solid-propellant engines will be provided by Thiokol Chemical, inertial guidance is being handled by the Eclipse Division of Bendix, fuzing and arming of the warhead is the responsibility of Bulova National Watch and the relatively simple transporter/erector/launcher (claimed to permit a launching to take place "in a matter of minutes" after arrival at an unprepared site) is being designed by the Accessories Division of Thompson Products.

It is particularly worth noting that a high proportion of the development of this weapon system has been farmed out to industry, representing a considerable *volte face* from the "arsenal concept" previously adhered to by the U.S. Army. The overall programme is likely to be large and of long duration, and deliveries should begin in a little more than two years.

Pershing: overall length, probably about 35ft; body diameter, probably greater than that of Redstone; launching weight, probably about 30,000 lb; design range, initially 500 miles.

POLARIS

United States Navy (Fleet Ballistic Missile System).

Type: Intermediate-range ballistic missile, for launching from submarines and possibly other naval vessels. Drawing: p. 873.

FOR at least four years the U.S. Navy have been interested in the concept of the large ballistic missile fired from a fighting ship (in particular from a submarine). At one time it was hoped that the Jupiter IRBM could be made acceptable to both the U.S. Army and Navy, but at an early stage it was appreciated that such a marriage would be impossible and the "divorce" took place at the end of 1956. From that date the Navy have been intensively developing their own Fleet Ballistic Missile System. So stringent are the requirements that no compromise can be tolerated, and the resulting system is quite remarkable. The vehicle itself is named Polaris, and it can truly be regarded as a second-generation weapon; it utilizes the latest techniques and represents a significant advance over the first-generation missiles previously developed by the Army and Air Force.

Overall direction of the FBMS is vested in the Special Projects Office of the Navy Bureau of Ordnance; system manager and prime contractor is the Missile Systems Division of Lockheed Aircraft at Sunnyvale, Cal. Lockheed are responsible for the design and fabrication of the airframe and nose-cone and for integration of all parts of the airborne portions of the system. Initially the FBMS was regarded as a relatively long-term project, yet, although it has been officially described as "the most complicated weapon system ever undertaken," its potential is so great that the development cycle has been reduced to a fraction of that originally envisaged. Existing equipment has been employed to accelerate the programme wherever possible; for example, the X-17 research vehicle—also produced by Lockheed—has been extensively employed, and many special test vehicles have been used for particular *ad hoc* tests. The team of subcontractors have already achieved several major "break-throughs" which will have repercussions for many years to come. It is now expected that the overall development cycle will be a bare 36 months, and that the system will be operational by October 1960.

Polaris is a two-stage weapon. Both stages employ a solid plasticized propellant with a very high specific impulse, contained within a thin-walled cylinder of high-strength steel. At the forward end the cylinder tapers to a diameter of about 20in. The propulsion section of the missile then terminates at a transition ring, to which is attached the warhead and re-entry body; the latter is a cylindrical assembly some 4ft in length capped by a nose-cone of unusual character.

Pioneer work on the Polaris propulsion system was accomplished by Thiokol Chemical, who employed techniques evolved from those developed for Sergeant. Further development and production is being handled by Aerojet-General at their solid propellant plant near Sacramento. Thiokol are being retained in the programme, and may be involved in the manufacture of production propulsion systems.

First-stage propulsion is provided by a grain of propellant approximately 110in in length and 53in in diameter. In order to reduce overall length and improve the control of the weapon during the launching stage, this charge exhausts through four nozzles. Each nozzle is provided with a curved deflector which can be gimballed to control the direction of the jet issuing from that nozzle. Known as Jetavators, these vanes are stated by *Aviation Week* to be "supported by bushings incorporating a stainless-steel split inner ring enclosed in Met-L-Flex knitted Inconel housing . . ." Temperature-resistant jacks are employed to actuate all four Jetavators in an unusual manner.

In the undeflected position the Jetavators cause no loss of thrust, and they are brought into use only when correction to trajectory is required. When one jet is deflected it creates a yawing moment sufficient to effect the required trajectory correction, and the resultant aggregate loss in propulsive effect is compensated for by slightly postponing the time of final cut-off. Until recent months, cut-off has been a major problem with solid propellants; it is reported that the Polaris chamber can be vented at the forward end, the reduced pressure causing almost instantaneous cut-off and having a repeatability high enough to ensure that the final flight velocity is almost exactly that required.

Second-stage propulsion is provided by another grain of propellant with the same 53in diameter but only 47in long (this charge must have the appearance of the traditional cheese). Separation between the two stages occurs roughly one-quarter of the way down the maximum-diameter part of the body. Around the top of this section are four small nozzles which appear to be verniers for precise control of trajectory during firing of the second stage. Presumably the second-stage nozzle (or nozzles) will have a total throat area less than that of the four nozzles of the first stage; in fact, the entire second-stage charge may be expelled through the four vernier nozzles previously mentioned. Thus the burning time of the second stage will be much greater than that of the high-thrust first stage, the latter being employed as a booster and the second stage as a sustainer. Both propulsion sections incorporate a plasticized-rubber propellant, possibly including some finely divided aluminium to increase the specific impulse. The grains are packed directly into the missile body, which is fabricated from steel with a u.t.s. which should shortly reach more than 220,000 lb/sq in. Chamber pressure is of the order of 1,000 lb/sq in, and wall thickness at present is unofficially reported to be 0.07in. Temco are assisting in the production of these remarkable thin-walled casings.

Navigation problems for FBMS are immense, involving both the missile and the carrying vessel. The system contractor, the Missile and Ordnance Systems Department of General Electric, has said: "Difficulties . . . result from submarine motions caused by its own speed, by ocean currents and other turbulences, the earth's rotation, atmospheric influences over the long range of the missile and from many factors of electronic complexity and system operation requirements. Launching a Polaris will not be an instantaneous operation but a continuous affair . . . a geo-ballistic computer in the submarine will work constantly plotting the vessel's location . . . It will pass data to fire-control computors for combination with information about ship's motions and other influences. The data will be converted from analogue to digital form. All further changes in location and other launching conditions will be accounted for and corrections continuously made. Just prior to launching, the fire-control will feed its data to the digital computer in the Polaris guidance system, maintaining a constant correction until the missile is launched. After launching, the inertial guidance system in the missile will take complete control."

It seems likely that Polaris has the most highly developed airborne guidance yet evolved. Consisting basically of a digital computer for remembering the fire-control data and a stable platform against which the memory can be checked, the entire airborne system is incorporated in a miniaturized package, which is amenable to the high acceleration when the

As outlined in the text, the Polaris, missile portion of the U.S. Navy Fleet Ballistic Missile System, can be launched from a submarine-mounted tube under pneumatic or steam pressure. This photograph shows a land test

first stage is firing yet has a weight believed to be less than 200 lb (in fact, it has been unofficially suggested that the system may weigh 1/7th as much as similar systems employed in the land-based IRBMs). The ship-borne part of the FBMS is, of course, the Ship's Inertial Navigation System, developed by the Massachusetts Institute of Technology (and manufactured by Sperry) which gives latitude and longitude, precise azimuth and local vertical.

In spite of its diminutive size, the warhead has a yield of at least 0.1 MT. The weight has been reported to be 650 lb, and several writers have suggested that future versions of Polaris will have a yield almost equivalent to that of the land-based IRBMs, i.e. 0.8-1 MT. The nose-cone ahead of the warhead is a blunt assembly developed jointly by Lockheed and the NASA (formerly the NACA), and it has been proved satisfactory during numerous firings of X-17s modified to the configuration known as "Polaris junior grade." There is much evidence that part of the cone is fabricated from beryllium, marking a major technical advance. Under certain conditions, however, beryllium can produce a toxic atmosphere, and this has been found to be a problem when a nuclear-submarine crew are confined submerged for a period of weeks. Possibly a phenolic/asbestos ablating skin of Army type will be standardized.

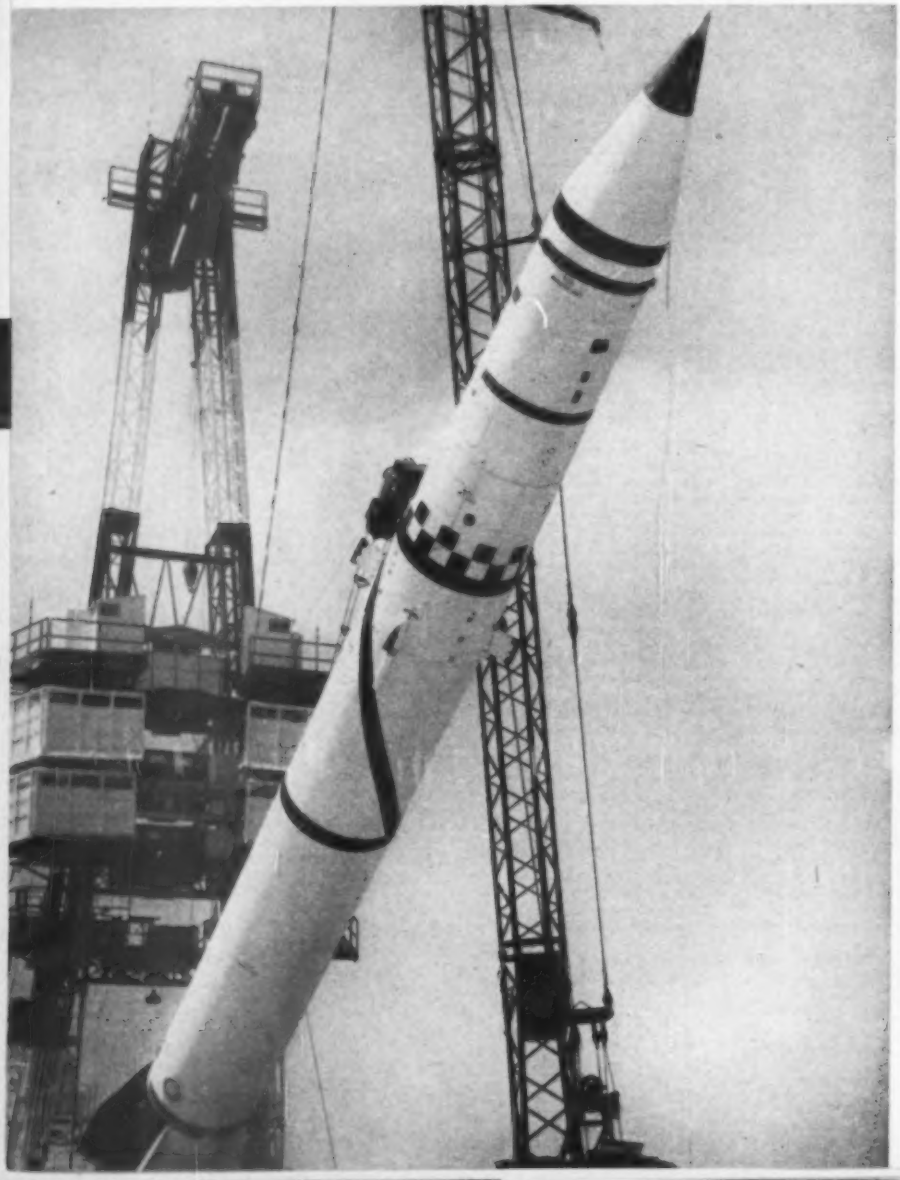
Polaris has been designed in parallel with the giant nuclear submarine which will carry it. The first three of the latter, designated SSBN-598, 599 and 600, are at present under construction (two by Electric Boat Company and one at Mare Island Navy Yard) for delivery in 1959 and 1960. Price of SSBN-598 is $105m and subsequent craft $85m. Each will have a displacement of 5,600 tons and will carry sixteen Polaris in a vertical position amidships. When a missile is required it will be moved by a conveyor system and released by compressed air from a hatch near the bows. At present it is envisaged that the Polaris first stage will not be fired under water; instead, the missile will be floated up from a depth of 100ft and fired just as the nose-cone breaks the surface. Alternatively, the missile will actually be fired like a torpedo from a substantially vertical tube carried by the submarine. This technique would place the mouth of the tube at the surface of the sea; after draining the tube and loading the Polaris, compressed air or steam would be used to blow the missile to a height of between 50 and 100ft before firing the first stage. Westinghouse are contractors for this system and the photograph (previous page) shows a test vehicle being fired from such a tube.

Lockheed's original contract for $20.5m was supplemented in October 1957 by $62.1m, and the fiscal year 1958 budget requested was $350m, of which $296m will buy the first three submarines plus ancillaries, $22.2m will cover research and development and $31.8m missiles and facilities. Under fiscal year 1959 $1.3b is being assigned for six more submarines, and it is expected that by 1970 the U.S. Navy will have more than forty such vessels in commission. Firings from fixed launchers began at Cape Canaveral early this year. Numerous flights have been made to check out sub-systems, airframe strength, guidance and control (spectacular failures have occurred during deliberate manœuvres beyond the design strength of the airframe), and the weapon is scheduled to go to sea shortly aboard U.S.S. *Observation Island* (successor to *Compass Island*, used in the development of the Ship's Inertial Navigation System), which will carry and fire two Polaris under relatively representative conditions.

As previously noted, SSBN-598 is scheduled to be operational in October 1960. Present efforts are devoted mainly to evolving a lighter propellant case and warhead, improving the specific impulse to obtain the full design range and reducing the reaction time. Incidentally, the potency of the FBMS has so disturbed the U.S. Navy that a desperate programme is now in hand to devise means of detecting possible enemy missile-carrying submarines at ranges greater than 1,000 miles.

Polaris: overall length, between 26ft 6in and 28ft; overall diameter, 54in; launching weight, 29,000 lb; first-stage thrust, over 100,000 lb; burn-out speed, approximately 10,000 m.p.h.; design range, 1,500 nautical miles.

One of the longest ballistic missiles is the U.S. Army's Redstone. This photograph, taken at Cape Canaveral, shows a stage in a firing handled entirely by the 40th Field Artillery Missile Group (Redstone); the missile is being hoisted into its vertical firing position



REDSTONE

United States Army (field artillery missile battalions); the missile is designated M5.

Type: Large tactical ballistic missile for battalion use with high-yield warhead. Drawing: p. 873.

AN extensive appraisal of this impressive weapon was contained in our issue of May 23 last. It was the first product of the Development Operations Division of the Army Ballistic Missile Agency at Huntsville, Alabama, and in view of the fact that the head of the division is Dr. Wernher von Braun, it was logical to base the design of the missile on the German A.4 (V-2). Like the classic German weapon, Redstone has a rocket motor with a single fixed chamber running on liquid oxygen and alcohol, jet deflection being accomplished by refractory vanes stationed immediately downstream of the propulsive nozzle. A separable nose-cone and re-entry body is employed, with stabilization by small fins. It is much longer than usual in the Redstone illustrated on the left.

Guidance is of the pure inertial variety, the prime contractor being Ford Instrument Division of Sperry Rand Corporation, and air-bearing gyros being employed. Operationally the motor and tankage sections are assembled to the 20ft fore-body in the field. The complete round is then raised—by means of a winch and A-frame—into the vertical position, standing on its simple ring-type launcher. The latter can be precisely positioned in azimuth before the missile is launched. The aft section, thrust unit and warhead are carried on separate Fruehauf transporters towed by Food Machinery tracked prime-movers. The weapon system includes a four-trailer liquid oxygen plant with an output of 20 short tons per day. It is believed that the design range was 465 miles, but that the decision to use a high-yield warhead with a weight of 3 tons has reduced this figure to the distance stated below. The powerplant is the Rocketdyne A-6, which weighs 1,450 lb, gives 75,000 lb thrust and incorporates a 780 h.p. turbopump. No vernier is used, the precision of cut-off being all-important.

Well over 100 Redstones must now be in U.S. Army service. The 40th Field Artillery Missile Group (heavy) was activated in July 1957 at Redstone Arsenal; the 4th Battalion of the 333rd Field Artillery was activated at Fort Sill on October 1st, 1957, and the 2nd Battalion of the 333rd at the same establishment in February 1. Battalions are being organized into field artillery missile groups of some 600 men, with complete mobility and ordnance and engineering support. Redstone production—handled by Chrysler's Defense Operations Division—should total about 1,000 and may finish next year.

M5 (SSM-A-14) Redstone: overall length, 63ft; body diameter, 70in; fin span, 12ft; launching weight, 45,000 lb; range with usual warhead, 200 miles.

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SEASLUG, the Royal Navy's new ship-to-air guided missile, has been tested and proved under service conditions. It has been designed and developed by Sir W. G. Armstrong Whitworth Aircraft Ltd. in collaboration with The General Electric Co. Ltd. and Sperry Gyroscope Co. Ltd.

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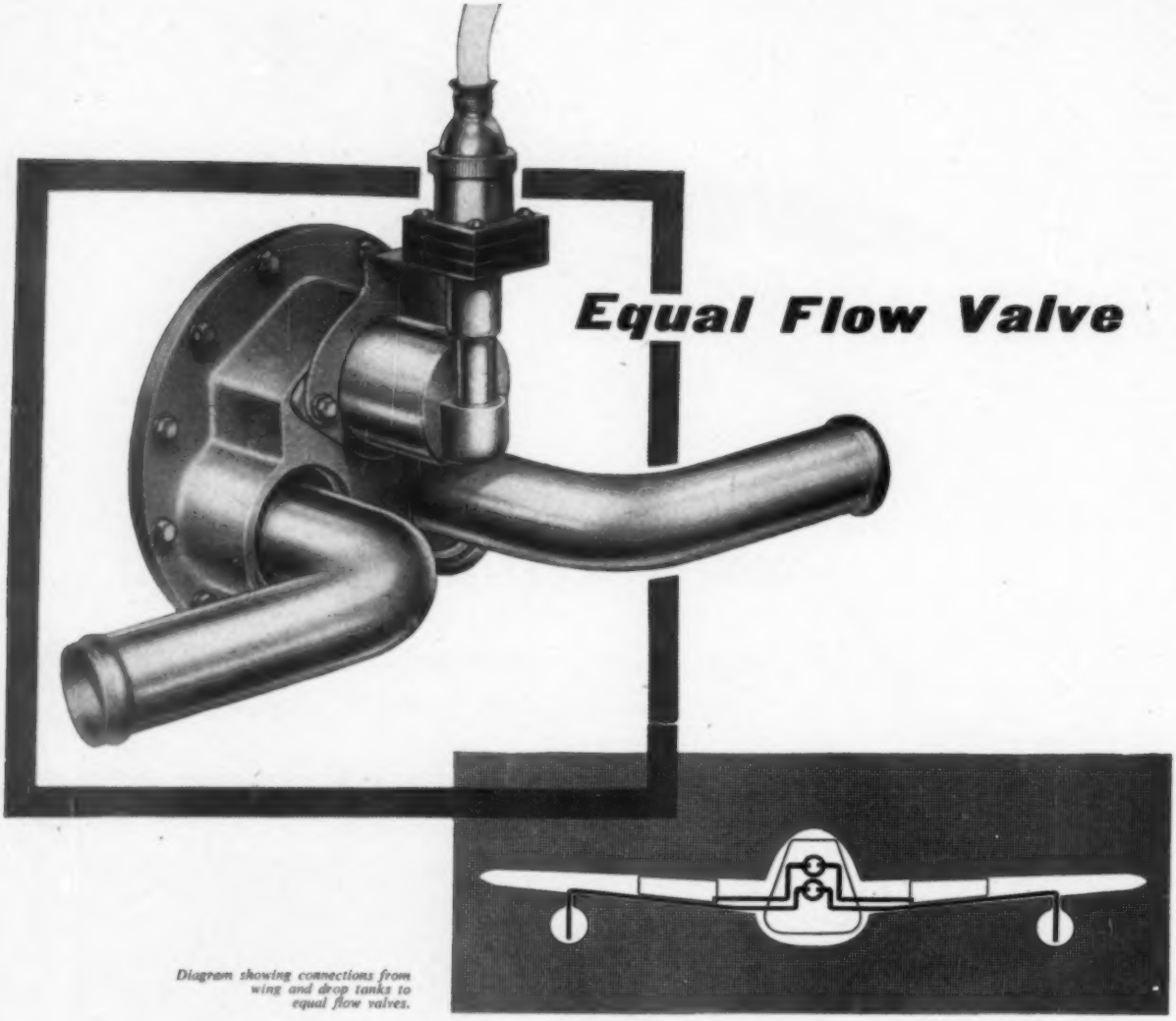

Diagram showing connections from wing and drop tanks to equal flow valves.

The Equal Flow Valve is a comparatively new development and shows a considerable saving in weight over components having a similar function. The valve permits a pair of wing tanks or drop tanks to be emptied symmetrically, by air pressure, into a central fuselage tank from which the engine feed is taken. The type illustrated has a flow capacity of 300 gallons per hour and is intended for installation in a symmetrical system. (Asymmetric systems can however be catered for by re-calibration.)
The valve has been test flown and proved; it maintains equal flow at all times, even under aerobatic conditions.
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TA1134

RUSSIAN Ballistic Missile

Soviet Union (Army); designation unknown, but reported to be T-1 or M-101.

Type: Medium-range ballistic missile. Drawing: p. 873.

IN November 1957 the Red Army put two of these missiles into the Revolutionary Anniversary parade through Red Square. Clearly a descendant of the German A.4 (V-2), the Soviet missile can be considered a counterpart of Redstone, although it is smaller than the American weapon and probably has longer range.

Propulsion is provided by a single motor with a fixed chamber, and refractory vanes are stationed in the exhaust (see our 1957 review, p. 878). Thrust of this motor is reported to be 77,000 lb, and the propellants as liquid oxygen and alcohol. A high-explosive or nuclear warhead is carried in the pointed nose-cone, which apparently does not separate. The missile is carried completely assembled on an articulated trailer towed by a large half-track vehicle which also accommodates a crew of 16 exclusive of those in the cab. The weapon system must include a launcher and a crane.

Russian MRBM: length, about 55ft; body diameter, 5ft 5in; fin span, about 11ft 9in; launching weight, of the order of 30,000 lb; thrust, about 77,000 lb; range, probably about 500 miles.

RUSSIAN ICBM

Soviet Union (Soviet Army); designation unknown.

Type: Intercontinental ballistic missile. Drawing: No reliable information on appearance available.

RUSSIA fired a ballistic missile with a range of several thousand miles in July 1957. According to *Aviation Week*, the missile travelled from Krasnyy Yar (the head of the range, near the Caspian Sea, also known as Kapustin Yar) a distance of 3,750 miles to the Bay of St. Peter, near Vladivostock. An official announcement was made by Tass in the following month, describing the firing as successful.

According to several unofficial publications the missile is designated T-3 or M-104, and is a three-stage device burning liquid oxygen and kerosine. It can obviously carry a very large warhead, and the ability of the Russians to place relatively huge satellites in orbit is proof of the existence of highly developed ballistic hardware of very great size indeed. Recently a Maj-Gen. G. I. Pokrovsky published a statement in a semi-technical Russian journal describing a form of Atlas-like radio-inertial guidance, and quoted a design impact circle with a radius of 6 miles. It is a current U.S.A.F. belief that this weapon is now becoming operational.

SERGEANT

United States Army (and possibly one or more NATO armies at a future date).

Type: Solid-propellant ballistic missile for Army use. Drawing: p. 873.

FOR more than a decade the Jet Propulsion Laboratory of the California Institute of Technology, north of Pasadena, Cal., have been developing ballistic vehicles for both research and the requirements of the U.S. Army. Best known of these is the Corporal (*q.v*); Sergeant is designed to replace the earlier weapon and to improve upon its performance in every respect. Experience with Corporal has been put to good use, and the new weapon system has improved field handling and storage, unjammable guidance and a much simplified and lighter array of ground equipment.

Following basic research and design by J.P.L., the weapon system was turned over to the Sperry Rand Corporation early in 1956 by Redstone Arsenal. Since that time Sperry have been production contractor, in association with J.P.L. who have continued to handle the study, research and development phases. Production of the weapon system, including erector/launcher, servicing, handling and maintenance equipment, is the responsibility of the Sperry Utah Engineering Laboratory at Salt Lake City.

Compared with Corporal, Sergeant is appreciably shorter, and it has a solid-propellant motor by Thiokol Chemical Company, produced at that company's Longhorn Division. The propellant is a cast charge of a polysulphide type, and until the advent of Polaris was probably the largest solid sustainer made. Chambers are manufactured by Excelco Developments.

Sperry Gyroscope Company and Minneapolis-Honeywell jointly produce the guidance system, which is reported to be a very simple inertial arrangement designed to control the flight over a pre-computed trajectory. Range is apparently determined by varying the pitch control, azimuth being set up accurately before launching. Servo controls by Lear are incorporated, and—like Corporal—both aerodynamic and jet-deflection controls are employed. Various types of high-explosive and nuclear warhead can be fitted.

Unlike the earlier weapon (or any other ballistic missile), Sergeant does not stand on its tail before firing. Instead, it is held in a near-vertical position by the dual-purpose erector/launcher. All portions of the Sergeant system are transportable by standard Army vehicles or transport aircraft. Progressive testing has been taking place at White Sands, and it is expected that a complete operational battalion will number fewer than 200 men. Several thousand rounds may be manufactured and the appropriation for fiscal year 1959 is $44m.

Sergeant: Length, approximately 32ft; body diameter, 36in; fin span, 92in; firing weight, 12,000 lb; thrust, 50,000 lb; burn-out speed, at least Mach 3.5; maximum range, 100 to 210 miles, depending on warhead.

THOR

Royal Air Force Bomber Command and United States Air Force (Strategic Air Command), the latter initially for instructional and indoctrination purposes; the weapon system is 315A and the missile portion is Strategic Missile 75.

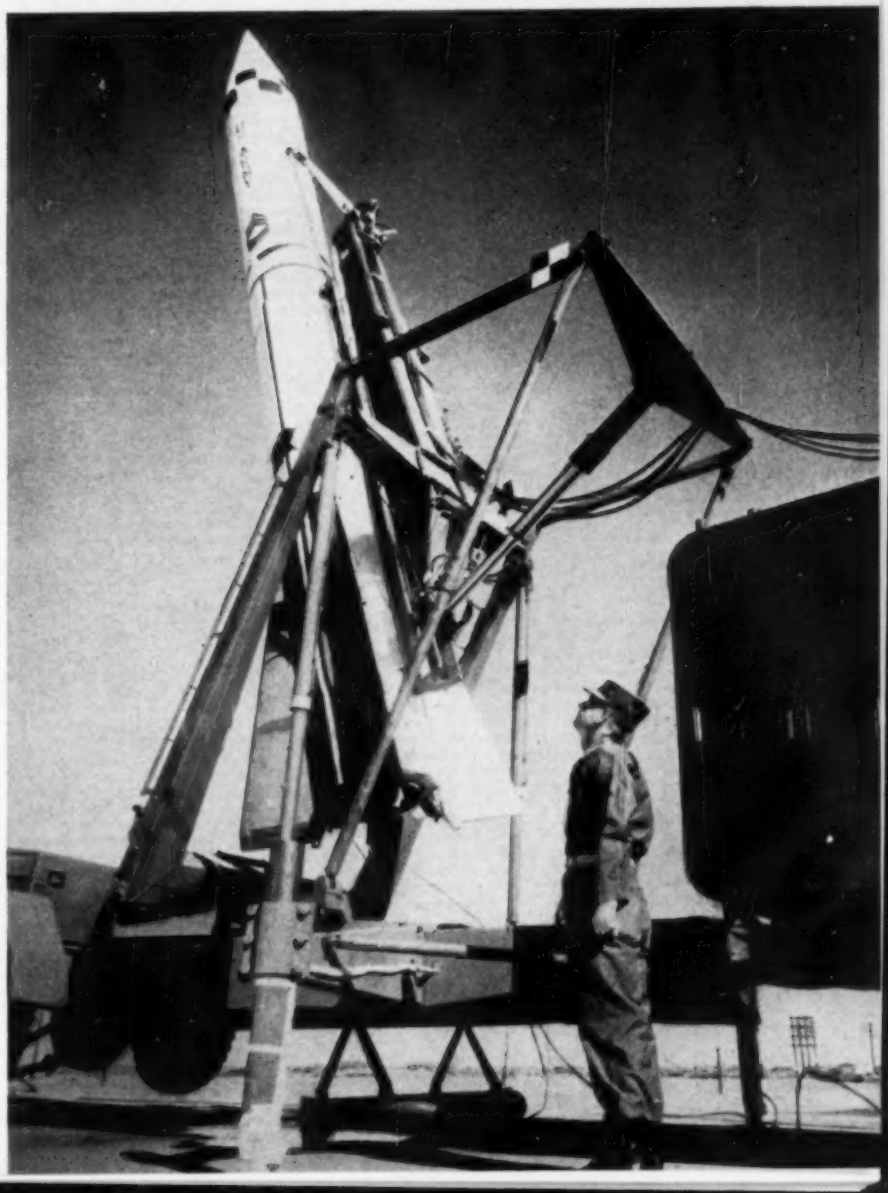
Type: Intermediate-range ballistic missile. Drawing: p. 873.

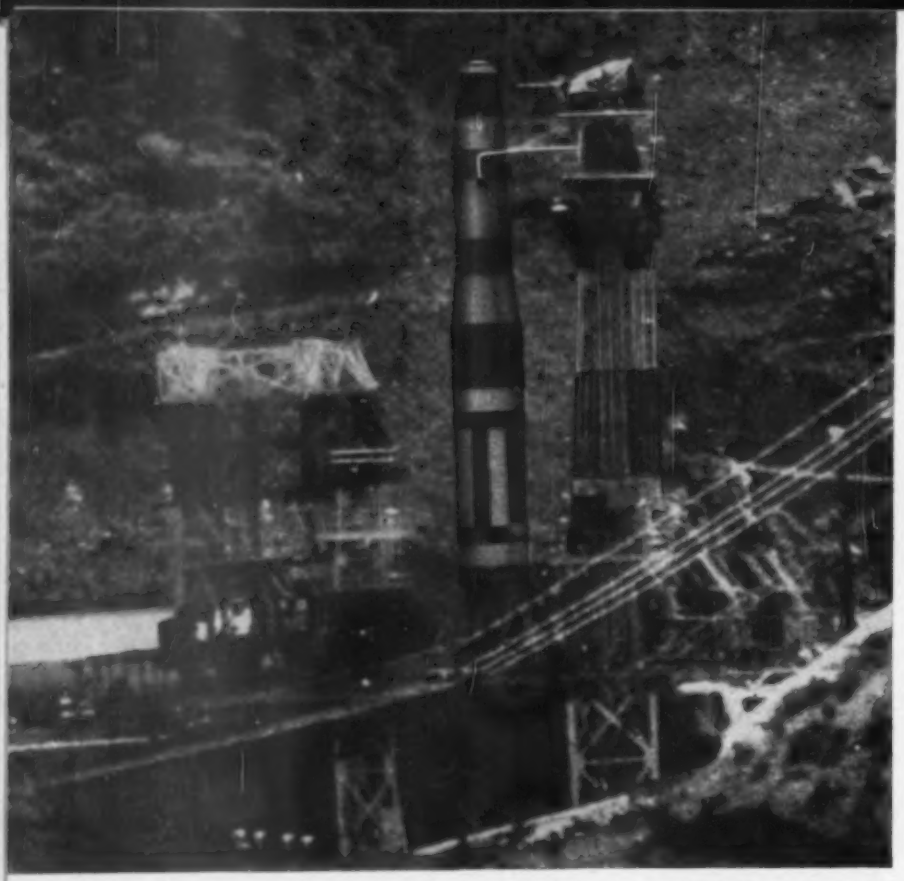
OWING to the fact that eleven pages elsewhere in this issue are devoted to WS-315A, it is proposed here to give only a brief résumé of the current status of the system.

Prime contractor is Douglas Aircraft, and propulsion and guidance are respectively the responsibility of Rocketdyne and A.C. Spark Plug. The SM-75 is designed to place a 1MT warhead on a target 1,500 nautical miles distant, and it is fired from a surface launcher. More than twenty must now have been fired, including two Thor-Able re-entry test vehicles (each of which carried a mouse to the South Atlantic) and three Thor-Able lunar probes (of which No. 2 almost succeeded in its mission around the moon).

It is not yet clear whether or not Thor will go into operational service with Strategic Air Command, but it seems probable. As outlined in the special article, each squadron will have fifteen rounds plus five spares, making a total system outlay of between $42m and $57m according to the type of ground equipment and

Unlike previous ballistic missiles, the U.S. Army's Sergeant is launched from an elevating ramp. This greatly speeds up ground handling and keeps the weapon under positive control at all times





Although not yet flown, the Titan has been extensively tested at the Martin plant at Denver and at Cape Canaveral. This "sneak" picture, taken with a telephoto lens from five miles away, shows an XSM-68 on one of the Martin stands at Denver

whether or not a liquid-oxygen factory is involved. Intensive training is being conducted by Douglas in a school at Tucson, and the first Thor squadron of R.A.F. Bomber Command has been formed near the village of Feltwell in Norfolk. By the summer of next year four squadrons of Bomber Command should be operational, this programme involving an outlay of $250m.

SM-75 Thor: overall length, 65ft; maximum body diameter, 96in; launching weight, 110,000 lb; re-entry speed, 10,000 m.p.h.; design range, 1,500 n.m. (1,727 statute miles).

TITAN

United States Air Force (Strategic Air Command); the weapon system is WS-107A-2 and the missile portion is Strategic Missile 68.

Type: Intercontinental ballistic missile for first-priority targets. Drawing: p. 873.

ALTHOUGH strictly a first-generation weapon, Titan is of more sophisticated design than Atlas. The prime contractor (The Martin Company, whose Denver Division was built for this weapon) have boldly adopted a two-stage configuration, with ignition of the second stage taking place in outer space. Titan is designed for vertical storage and for firing from "hard" (i.e., underground) installations; and its warhead is believed to have a higher yield than that of any other ballistic missile.

It was in 1955 that the U.S. Air Force agreed that the importance of the ICBM was so fundamental to Western security that it would be unwise to place complete reliance on one design. Accordingly, WS-107A-2 was instituted, making the maximum use of the scientific and engineering data accruing from WS-107A-1 while employing an entirely different missile configuration and radically new methods of storage and firing.

Unlike Atlas, the Titan airframe is principally manufactured from high-strength light-alloy (structural details were contained in our 1957 review), integral tankage, machined and chemically etched skin and precision heli-welding being involved. The first stage is approximately 50ft in height, including the motor chambers. At the lower end is the Aerojet-General XLR87-AJ-1 motor, which has two gimballed chambers, each of 150,000 lb thrust, running on liquid oxygen and RP-1. About 80 per cent of the energy transferred to the warhead comes from this stage, burn-out occurring at a point well outside the earth's atmosphere. At the first-stage burn-out point the complete missile is permitted to coast for a pre-computed period. Then the liquid-oxygen tank from the first stage is vented at about 40 lb/sq in through jets placed at diametrically opposed points on the rim at the upper end of the first stage. These jets produce an upward thrust against the second stage and are intended to ensure a clean separation.

Second-stage propulsion is also provided by Aerojet-General. Owing to the fact that it is ignited in a vacuum, the single gimbal-mounted chamber of the XLR91-AJ-1 sustainer is much larger than its 60,000 lb sea-level thrust would suggest. The second stage is approximately 35ft in length, and incorporates liquid oxygen and RP-1 integral tankage, with feed pipes carried in external fairings. Surprisingly, there are no fewer than four vernier motors, disposed at regular intervals around the base of the second stage.

In order to reduce the radar cross-section, the tankage of the second stage is separated from the nose-cone and re-entry body, and the latter is large enough for it to incorporate its own vernier propulsion at a later date. Within this unpowered "third stage" is the extremely interesting pure-inertial guidance system, the prime contractor for which is American Bosch Arma Corporation. Liquid-floated gyros with two degrees of freedom are employed, and the stable platform incorporates three B-1 accelerometers sensitive to within 0.000005g. The airborne system incorporates a remarkable digital computer produced by Remington Rand Univac Division. It is reported that during the first 300 sec of flight (a remarkably long period) guidance is effected by a fixed-frame platform and Minneapolis-Honeywell floated gyros, apparently supplemented by ground command by a Bell Telephone Laboratories radio system. Thereafter the trajectory is controlled by the Arma pure-inertial system. The latter, incidentally, being of a generation later than that of Thor, is appreciably lighter, weighing less than 500 lb. It seems that, in the present state of the art, the miss-distance of Titan is greater than that of the radio-inertial Atlas; but Titan's warhead should be more than adequate compensation and the independence of ground guidance renders salvo-firing practicable.

Future versions of Atlas are at present scheduled to employ an all-inertial system, which will almost certainly include the Arma equipment developed for Titan. Since Atlas is a relatively proven vehicle the U.S.A.F. are anxious to incorporate the self-contained guidance into it at the earliest possible date, and accordingly the first Arma/Minneapolis-Honeywell systems off the production line will be incorporated in the earlier ICBM. As a result, the first batch of Titans will necessarily have to resort to the G.E./B.T.L./Burroughs radio-inertial system employed in Atlas—a curious state of affairs.

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Titan's extensive ground-support equipment includes transtainers (transporter/containers) for both airframe stages produced by North American Aviation to Martin design, a Fruehauf transtainer for both engines, overall launching and handling equipment by American Machine and Foundry, launcher by Kaiser Steel and Baldwin-Lima-Hamilton, an erector and thrust-measurer by Space Corporation, fuelling equipment by A. O. Smith, Air Products and Flight Refueling, and electronic check-out vehicles by Bosch and Hallamore Electronics. First and second stages are stored separately, in the vertical position. Each stage can be fired on the ground, and the "battleship" stand at Denver has for several months been engaged in firing both stages side-by-side, the firings being sequenced to simulate a complete mission.

Four pads are now virtually complete at Cape Canaveral and the first launching of an XSM-68 must now be overdue. Another pad is well advanced at the new Pacific Missile Test Range, and some fairly intensive firing will have to be done next year if the system is to be operational with S.A.C. by 1960 (as it should be under the present programme). It is generally considered that development is running about one year behind Atlas, and in August of this year the top-priority rating previously enjoyed by Titan was removed. The supplementary budget for the current fiscal year includes between $50 and $100m to accelerate the system development and base construction, this money being sufficient for one hard base below ground or two soft pads on the surface. According to *Aviation Week* it is at present expected that all Titans will in fact be sited underground. A New York engineering firm is at present engaged in a study of tunnels, shaft closures and ventilation to prove the feasibility of hard sites.

SM-68 Titan: overall length, approximately 85ft; first-stage diameter about 115in; second-stage diameter about 70in; launching weight, 221,000 lb: design range, 5,500 n.m. (6,333 statute miles).

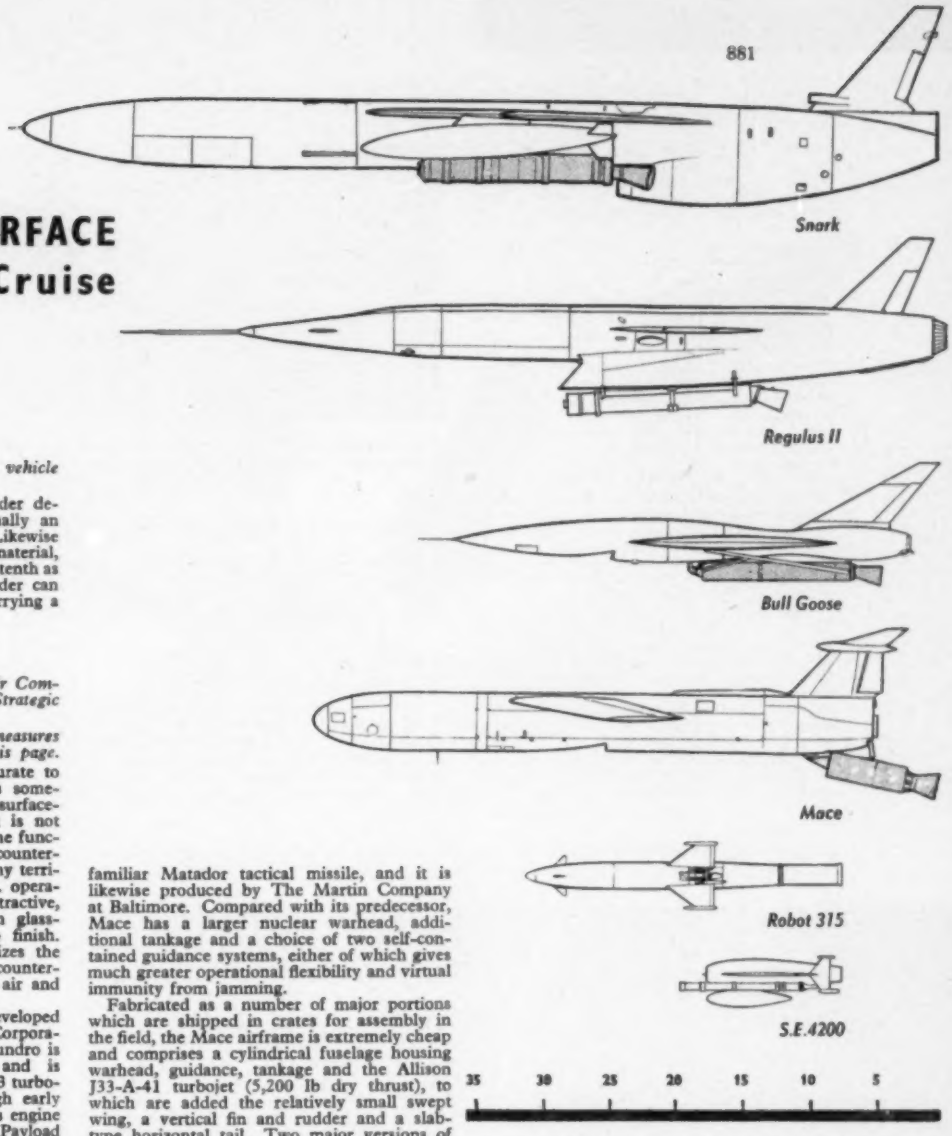
UNDESIGNATED

United States Air Force (Strategic Air Command).

Type: Medium-range ballistic missile for launching from a manned bomber.

SINCE early 1957 basic project work has been in hand on a ballistic missile suitable for launching from a bomber. Companies chosen to submit tenders are said to include Bell Aircraft, Boeing, G.E., Martin and North American. The carrier vehicle will be the B-70 Valkyrie, and the missile may also have to fit the B-47, B-52 and B-58.

SURFACE TO SURFACE
Aerodynamic Cruise



GANDER

American private venture.

Type: Air-breathing, cruise-type vehicle with thermonuclear payload.

UNOFFICIALLY reported to be under development by Fairchild, this is virtually an offensive version of Goose (*q.v.*). Likewise fabricated from dielectric glass-fibre material, it is stated to present a radar target one-tenth as great as that of an F-86 Sabre. Gander can cruise subsonically for 2,000 miles carrying a payload with a yield of 1 MT.

GOOSE

United States Air Force (Strategic Air Command); the missile is designated Strategic Missile 73.

Type: Surface-launched countermeasures and diversionary vehicle. Drawing: this page.

POSSIBLY it would be equally accurate to class this unusual weapon—which is sometimes referred to as Bull Goose—in the surface-to-air section, since in most roles it is not expected to return to its base. Its prime function is to conduct a campaign of countermeasures near to, or deep inside, enemy territory in order to support other S.A.C. operations. The airframe is extremely attractive, being fabricated almost entirely from glass-fibre materials and having a superb finish. Use of a dielectric structure minimizes the radar cross-section, so that the countermeasures seem to emanate from thin air and not from a readily detected source.

A tailless delta, SM-73 is being developed by the Fairchild Engine and Airplane Corporation at Hagerstown, Md. (Paul Omohundro is principal airframe sub-contractor), and is designed to use the same company's J83 turbojet of about 2,000 lb thrust (although early flight trials were completed before this engine became available, as noted below). Payload comprises at least 1,000 lb of Ramo-Wooldridge e.c.m. systems, some of which are likely to modify the external appearance of the vehicle.

Goose bases are being established at Duluth Municipal Airport, Minn., and Ethan Allen A.F.B., Vt. The missiles are housed in simple shelters with roll-top lids like the traditional bread-box, and they are fired, by a solid-boost motor, from an exceedingly simple zero-length four-footed launcher. A.M.F. is principal sub-contractor for ground-support equipment. Flight trials began at Cape Canaveral at the beginning of this year, the first batch of XSM-73s all being powered by Armstrong Siddeley Viper 3s supplied by Curtiss-Wright. The extraordinary success of these trials is largely ascribed to the fact that the SM-73 was the first vehicle to be completely tracked tested before taking the air.

SM-73 Goose: length, approximately 38ft; span, approximately 18ft; firing weight, probably about 5,000 lb without booster; flight speed, up to about Mach 1.5; range, probably over 1,000 miles.

MACE

United States Air Force (Tactical Air Command, 12th Air Force in Europe and units in Formosa, Japan and probably Spain, North Africa and other locations); the missile portion of the weapon system is Tactical Missile 76.

Type: Medium-range, subsonic, air-breathing, cruise-type missile. Drawing above.

ORIGINALLY known as the TM-61B, the Mace is a greatly improved version of the familiar Matador tactical missile, and it is likewise produced by The Martin Company at Baltimore. Compared with its predecessor, Mace has a larger nuclear warhead, additional tankage and a choice of two self-contained guidance systems, either of which gives much greater operational flexibility and virtual immunity from jamming.

Fabricated as a number of major portions which are shipped in crates for assembly in the field, the Mace airframe is extremely cheap and comprises a cylindrical fuselage housing warhead, guidance, tankage and the Allison J33-A-41 turbojet (5,200 lb dry thrust), to which are added the relatively small swept wing, a vertical fin and rudder and a slab-type horizontal tail. Two major versions of Mace are in service. The TM-76A currently being delivered incorporates the novel Atran radar terrain-inspection system by Goodyear, which compares the actual appearance of the ground beneath with photographs or simulated pictures by visible light or infra-red—of how the terrain ought to appear. This is expected to have extraordinary accuracy, although the system emits a certain amount of radiation and is thus not completely immune from all electronic countermeasures. Numerous Atran-guided missions have been flown during the development of the TM-76A and T.A.C. squadrons are currently becoming operational with this version. The TM-76B uses the AChiever pure-inertial system by A. C. Spark Plug with an associated computer (different from Thor's).

TM-76 Mace: length, 44ft; span, 22ft 11in; launching weight (without 100,000 lb-thrust boost motor), 18,000 lb; cruising speed, 650 m.p.h. or Mach 0.9; maximum range, "over 650 miles".

MATADOR

United States Air Force (Tactical Air Command and many formations outside the U.S.A.); the missile is designated TM-61.

Type: Medium-range, subsonic, air-breathing cruise-type missile.

ONE of the most highly developed and the best-known of all bombardment missiles, the Martin Matador has now been in service with the U.S. Air Force for almost four years and has proved itself adequate to the demands imposed upon it. A full history and description was published in our 1957 review issue. The TM-61A, now in world-wide service, is equipped with the MSQ guidance system, which operates on radio command from forward observation stations and thus requires line-of-sight communications. The TM-61C, which may go into service with the Federal German Air Force, has a supplementary guidance system called Shanicle; this is likewise dependent on ground command, but in this case is a navigation system of the hyperbolic type employing two ground transmitters. Matador can carry a high-explosive or nuclear warhead weighing 3,000 lb, and is launched by a 50,000 lb-thrust boost motor. Cruise propulsion is provided by an Allison J33-A-37 turbojet of 4,600 lb thrust. Well over 1,000 TM-61s have been delivered; production has now ceased in favour of Mace (*q.v.*).

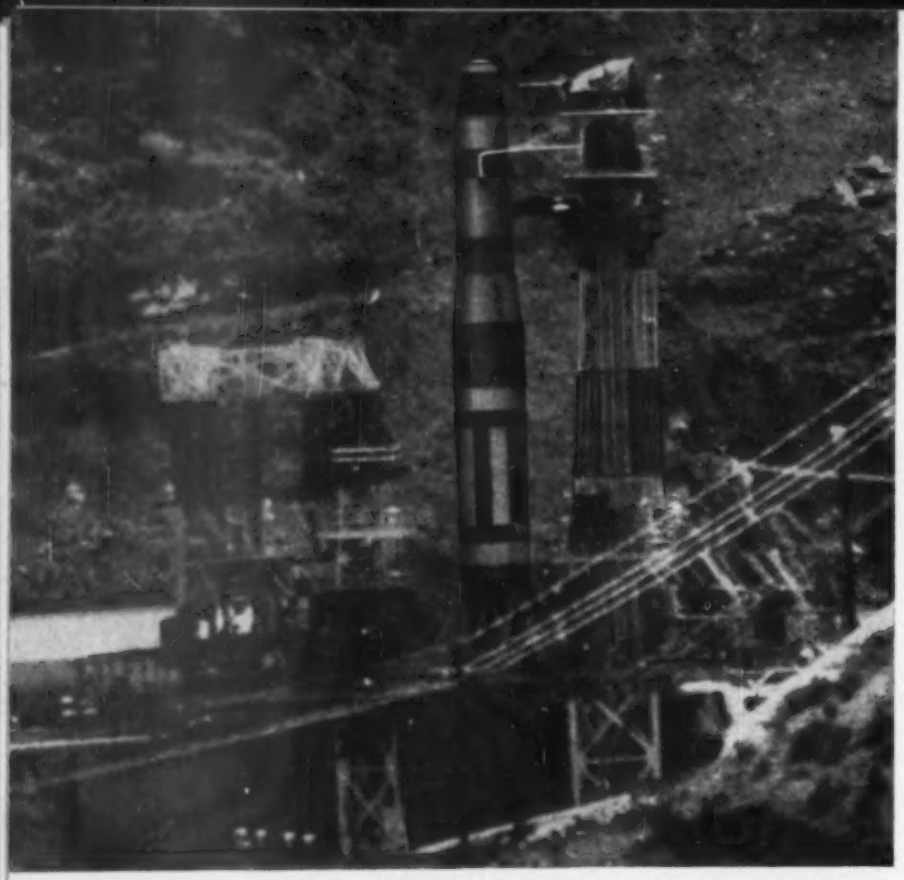
TM-61C Matador: length, 39ft 8.5in; span, 27ft 10in; launching weight (exclusive of boost motor), 12,000 lb; cruising speed, approximately 600 m.p.h.; theoretical range, over 500 miles (but in practice restricted by guidance considerations).

REGULUS I

United States Navy.

Type: Medium-range, subsonic, cruise-type, air-breathing missile.

REGULUS I is a 500-mile-range aircraft-type weapon, powered by an Allison J33 turbojet of 4,600 lb thrust. Launched by two 66,000 lb-thrust boost rockets, it cruises at almost Mach 0.9 and can take a nuclear warhead. It is carried in service by the large sub-



Although not yet flown, the Titan has been extensively tested at the Martin plant at Denver and at Cape Canaveral. This "sneak" picture, taken with a telephoto lens from five miles away, shows an XSM-68 on one of the Martin stands at Denver

MISSILES 1958...

whether or not a liquid-oxygen factory is involved. Intensive training is being conducted by Douglas in a school at Tucson, and the first Thor squadron of R.A.F. Bomber Command has been formed near the village of Feltwell in Norfolk. By the summer of next year four squadrons of Bomber Command should be operational, this programme involving an outlay of $250m.

SM-75 Thor: overall length, 65ft; maximum body diameter, 96in; launching weight, 110,000 lb; re-entry speed, 10,000 m.p.h.; design range, 1,500 n.m. (1,727 statute miles).

TITAN

United States Air Force (Strategic Air Command); the weapon system is WS-107A-2 and the missile portion is Strategic Missile 68.

Type: Intercontinental ballistic missile for first-priority targets. Drawing: p. 873.

ALTHOUGH strictly a first-generation weapon, Titan is of more sophisticated design than Atlas. The prime contractor (The Martin Company, whose Denver Division was built for this weapon) have boldly adopted a two-stage configuration, with ignition of the second stage taking place in outer space. Titan is designed for vertical storage and for firing from "hard" (i.e., underground) installations; and its warhead is believed to have a higher yield than that of any other ballistic missile.

It was in 1955 that the U.S. Air Force agreed that the importance of the ICBM was so fundamental to Western security that it would be unwise to place complete reliance on one design. Accordingly, WS-107A-2 was instituted, making the maximum use of the scientific and engineering data accruing from WS-107A-1 while employing an entirely different missile configuration and radically new methods of storage and firing.

Unlike Atlas, the Titan airframe is principally manufactured from high-strength light-alloy (structural details were contained in our 1957 review), integral tankage, machined and chemically etched skin and precision heli-welding being involved. The first stage is approximately 50ft in height, including the motor chambers. At the lower end is the Aerojet-General XLR87-AJ-1 motor, which has two gimballed chambers, each of 150,000 lb thrust, running on liquid oxygen and RP-1. About 80 per cent of the energy transferred to the warhead comes from this stage, burn-out occurring at a point well outside the earth's atmosphere. At the first-stage burn-out point the complete missile is permitted to coast for a pre-computed period. Then the liquid-oxygen tank from the first stage is vented at about 40 lb/sq in through jets placed at diametrically opposed points on the rim at the upper end of the first stage. These jets produce an upward thrust against the second stage and are intended to ensure a clean separation.

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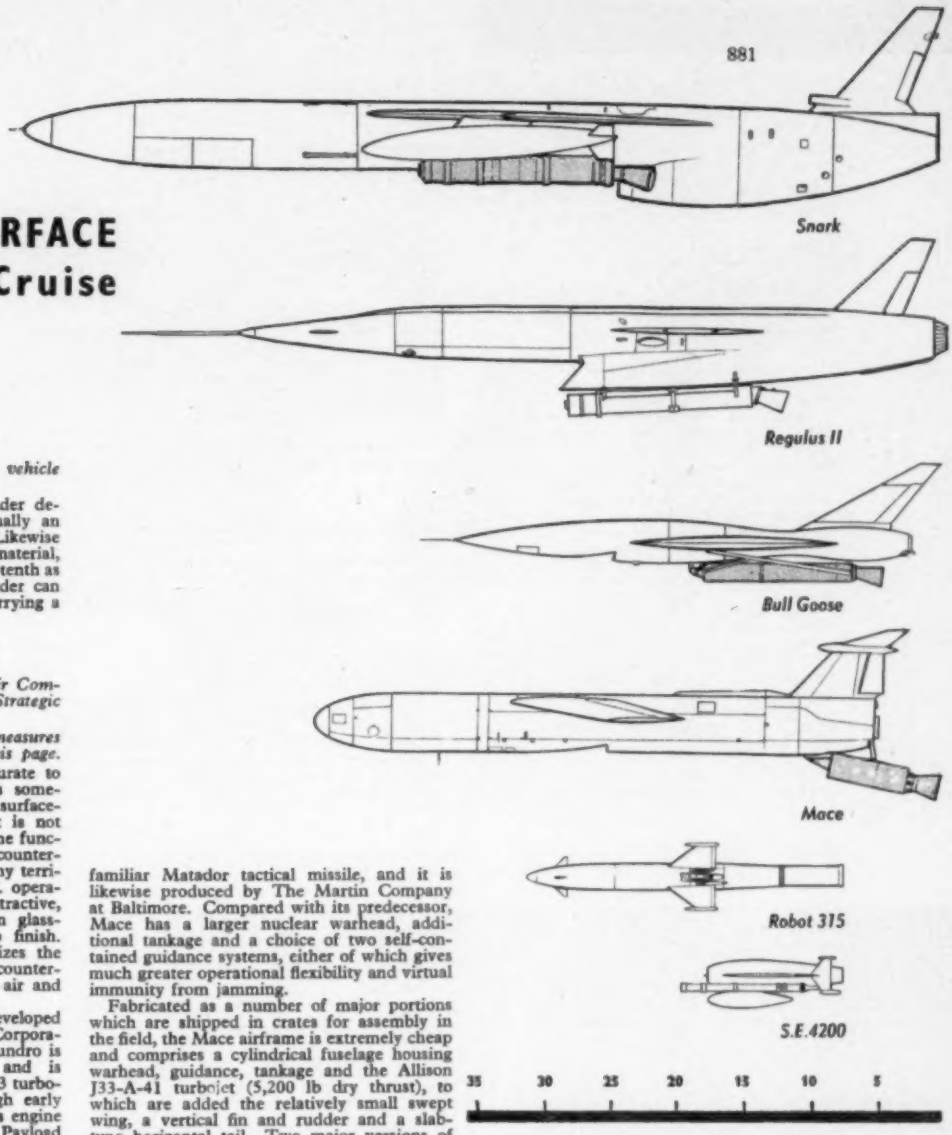
UNDESIGNATED

United States Air Force (Strategic Air Command).

Type: Medium-range ballistic missile for launching from a manned bomber.

SINCE early 1957 basic project work has been in hand on a ballistic missile suitable for launching from a bomber. Companies chosen to submit tenders are said to include Bell Aircraft, Boeing, G.E., Martin and North American. The carrier vehicle will be the B-70 Valkyrie, and the missile may also have to fit the B-47, B-52 and B-58.

SURFACE TO SURFACE
Aerodynamic Cruise



GANDER

American private venture.

Type: Air-breathing, cruise-type vehicle with thermonuclear payload.

UNOFFICIALLY reported to be under development by Fairchild, this is virtually an offensive version of Goose (*q.v.*). Likewise fabricated from dielectric glass-fibre material, it is stated to present a radar target one-tenth as great as that of an F-86 Sabre. Gander can cruise subsonically for 2,000 miles carrying a payload with a yield of 1 MT.

GOOSE

United States Air Force (Strategic Air Command); the missile is designated Strategic Missile 73.

Type: Surface-launched countermeasures and diversionary vehicle. Drawing: this page.

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SM-73 Goose: length, approximately 38ft; span, approximately 18ft; firing weight, probably about 5,000 lb without booster; flight speed, up to about Mach 1.5; range, probably over 1,000 miles.

MACE

United States Air Force (Tactical Air Command, 12th Air Force in Europe and units in Formosa, Japan and probably Spain, North Africa and other locations); the missile portion of the weapon system is Tactical Missile 76.

Type: Medium-range, subsonic, air-breathing, cruise-type missile. Drawing above.

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MATADOR

United States Air Force (Tactical Air Command and many formations outside the U.S.A.); the missile is designated TM-61.

Type: Medium-range, subsonic, air-breathing, cruise-type missile.

ONE of the most highly developed and the best-known of all bombardment missiles, the Martin Matador has now been in service with the U.S. Air Force for almost four years and has proved itself adequate to the demands imposed upon it. A full history and description was published in our 1957 review issue. The TM-61A, now in world-wide service, is equipped with the MSQ guidance system, which operates on radio command from forward observation stations and thus requires line-of-sight communications. The TM-61C, which may go into service with the Federal German Air Force, has a supplementary guidance system called Shanicle; this is likewise dependent on ground command, but in this case is a navigation system of the hyperbolic type employing two ground transmitters. Matador can carry a high-explosive or nuclear warhead weighing 3,000 lb, and is launched by a 50,000 lb-thrust boost motor. Cruise propulsion is provided by an Allison J33-A-37 turbojet of 4,600 lb thrust. Well over 1,000 TM-61s have been delivered; production has now ceased in favour of Mace (*q.v.*).

TM-61C Matador: length, 39ft 8.5in; span, 27ft 10in; launching weight (exclusive of boost motor), 12,000 lb; cruising speed, approximately 600 m.p.h.; theoretical range, over 500 miles (but in practice restricted by guidance considerations).

REGULUS I

United States Navy.

Type: Medium-range, subsonic, cruise-type, air-breathing missile.

REGULUS I is a 500-mile-range aircraft-type weapon, powered by an Allison J33 turbojet of 4,600 lb thrust. Launched by two 66,000 lb-thrust boost rockets, it cruises at almost Mach 0.9 and can take a nuclear warhead. It is carried in service by the large sub-

marines U.S.S. *Barbero* and *Tunny*, and has also been fired from many surface craft, conversion to accept this weapon system being simple. Further details and history were published in our 1956 review (December 7, 1956).

REGULUS II

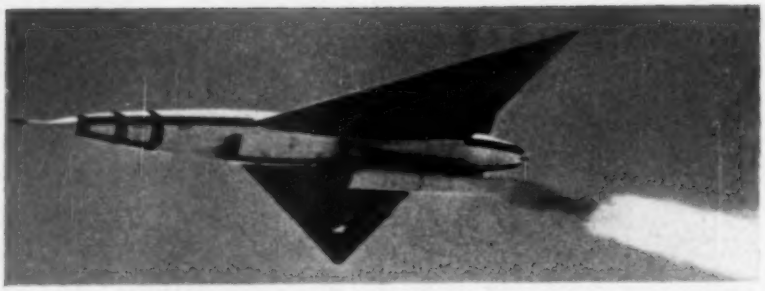
United States Navy.

Type: Medium-range, supersonic, air-breathing, cruise-type missile. Drawing: p. 881.

DEVELOPED, like its forerunner, by Chance Vought Aircraft Inc., Regulus II marks such an advance over Regulus I as to deserve a new name; no two parts are common to both weapon systems. The vehicle for Regulus II is SSM-N-9A. Powered by a General Electric J79-GE-3A turbojet with afterburner (reheat thrust 15,000 lb), this missile has a very advanced and attractive airframe. Both the wings and vertical tail fold for stowage in the submarine hangar, and the control surfaces comprise fixed foreplanes and powered elevons on the wings. Guidance incorporates radio-command by Stavid Engineering, a Sperry autopilot and the AChiever pure-inertial system by A.C. Spark Plug, the latter being used throughout the flight.

Like Regulus I, the first Regulus II test vehicles were recoverable rounds fitted with braking parachutes and landing gear, and the first of these began flying at Edwards A.F.B. on May 29, 1956. On November 13, 1957, a more representative vehicle was launched by its Aerojet-General boost motor of 115,000 lb thrust. On September 16 a Regulus II was fired from the submarine U.S.S. *Grayback*, and the missile will also be carried by the smaller ship *Growler* and by the forthcoming nuclear submarines *Halibut*, *Permit*, *Pollack* and *Plunger*, and by the nuclear cruiser *Long Beach*.

SSM-N-9A Regulus II: length (excluding probe), 57ft 6in; span, 20ft 1in (9ft 2in with wings folded); launching weight (excluding booster), 22,000 lb; speed, "beyond Mach 2"; range, "more than 1,000 miles"; altitude capability, "above 60,000ft".



The glass-fibre SM-73 Goose—or Bull Goose—is a countermeasures and diversionary vehicle, launched by a solid-propellant booster. Initial test flights were done on British-built Viper turbojets; production Geese will have the Fairchild J83

ROBOT 315

Royal Swedish Navy.

Type: Air-breathing, cruise-type bombardment weapon for firing from destroyers and similar-sized surface vessels. Drawing: p. 881.

THE history of this unusual missile was outlined in our 1957 review (p. 880). The first truly representative 315 was launched in January 1954, and the missile is today highly developed and in operational service. Two destroyers, *Halland* and *Smaland*, are each equipped with a launcher and magazines for 315s, and the former ship has been conducting firing trials since April 1955.

As the drawing indicates, there are cruciforms of delta wings and control fins, the latter being mounted closer to the nose than are those of Robot 304 (p. 888). All-weather guidance is fitted, and the missile is certainly large enough to carry a nuclear warhead. Launching is effected from a gently sloping ramp, under boost propulsion from four solid rocket motors with nozzles flush with the fuselage between the trailing edges of the wing. Cruise propulsion is provided by an unusual form of pulse-jet engine, apparently with an intake around the fuselage in line with the wings.

Largest of the air-breathing missiles, the intercontinental Snark is now in inventory service with Strategic Air Command. One is here departing under the thrust of its two 130,000-lb boost motors

S.E.4200

French Army.

Type: Air-breathing, cruise-type bombardment vehicle. Drawing: p. 881.

THIS diminutive miniature aeroplane is in small-scale service with the French Army, and offers high effectiveness against poorly defended targets for a very modest cost. The basic vehicle comprises an integral ramjet body, supported by a large mid-mounted wing carrying trailing-edge elevons and tip-mounted rudders. The payload is slung in a streamlined pod beneath the fuselage. The missile is launched under the thrust of two or four boost motors from a simple ramp inclined at about 25 deg. Guidance is effected by radio command, tracking being assisted by bright flares carried on the fins, and at the appropriate moment the missile is put into a dive on to its target. Guidance is obviously the limiting factor restricting the range.

S.E.4200: length, approximately 10ft (about 12ft 6in with boosts); wing span, 7ft 1in; firing weight, 660 lb; flight speed, about Mach 0.9; theoretical ultimate range, up to 125 miles.

SNARK

United States Air Force (Strategic Air Command); the vehicle itself is Strategic Missile 62A.

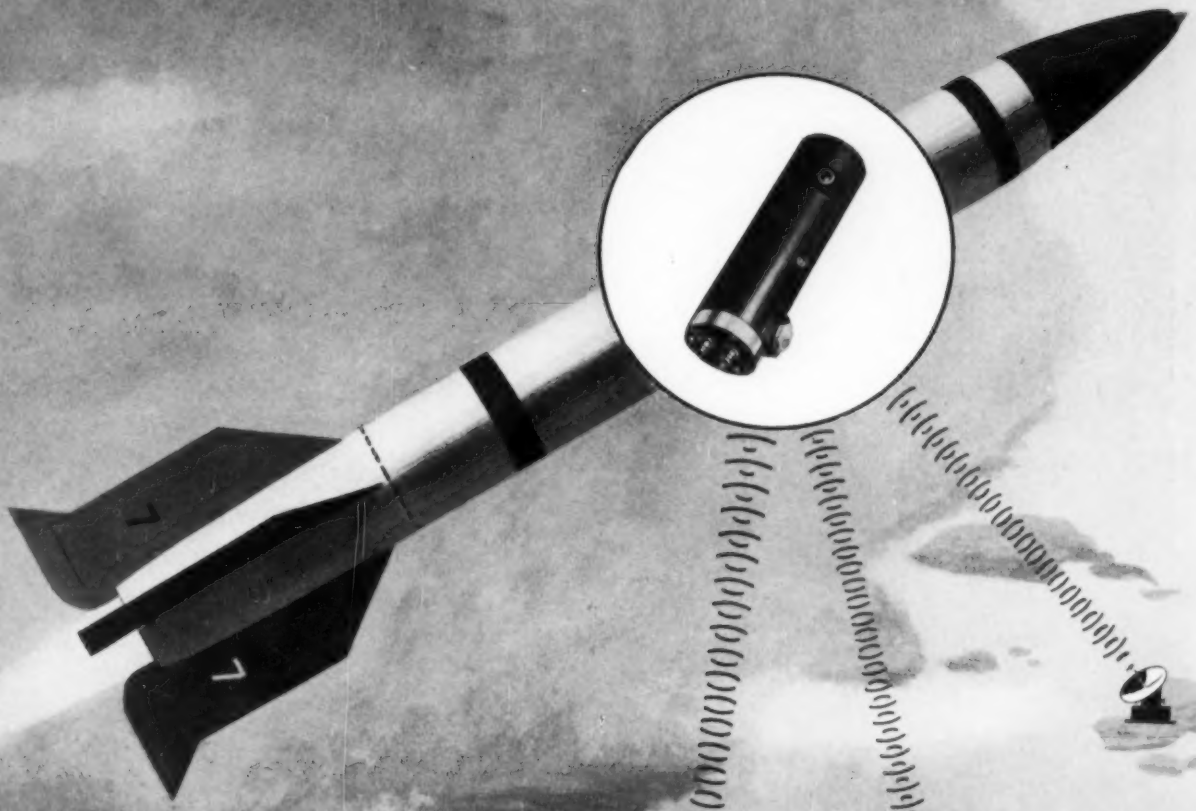
Type: Intercontinental, air-breathing, cruise-type missile. Drawing: p. 881.

ALTHOUGH it could have been edged off the map by the manned bomber and the ballistic missile, the SM-62A Snark is now in inventory production and is on the point of becoming operational with S.A.C. squadrons. The complete weapon system is managed by Northrop Aircraft.

History was published in our 1957 review issue. The decision to place Snark in the S.A.C. inventory was taken in April 1957. A production order for $73 came in July, and follow-on orders have since totalled about $140m. Discounting about $30m assigned to research and flight-testing, this represents a total to date of at least 50 specimens for user squadrons.

As was outlined in more detail in our 1957 review, the vehicle is devoid of a horizontal tail; the highly efficient wing carries divided elevons (the only control surfaces) and there is

OPERATION BACK-TALK



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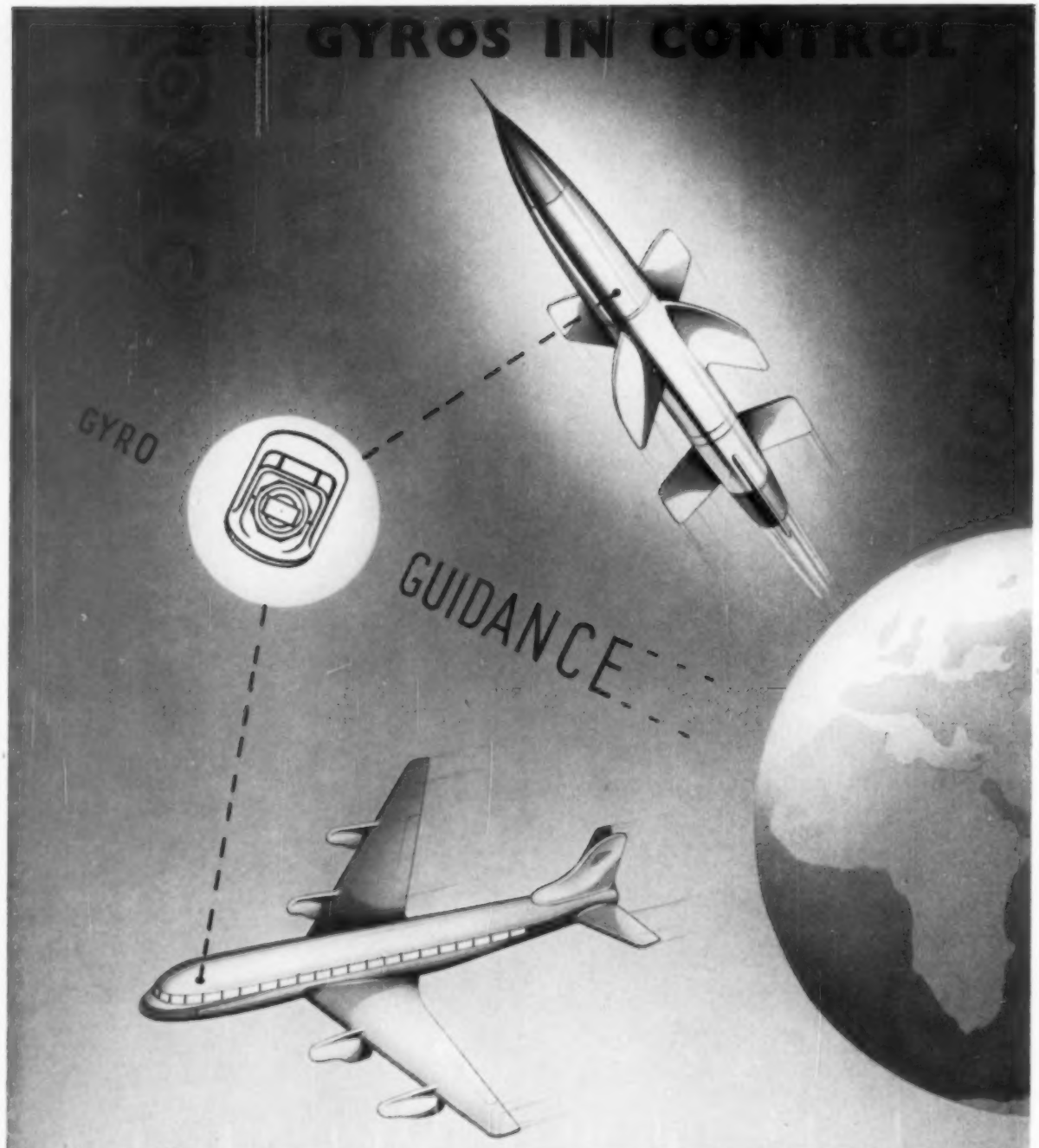

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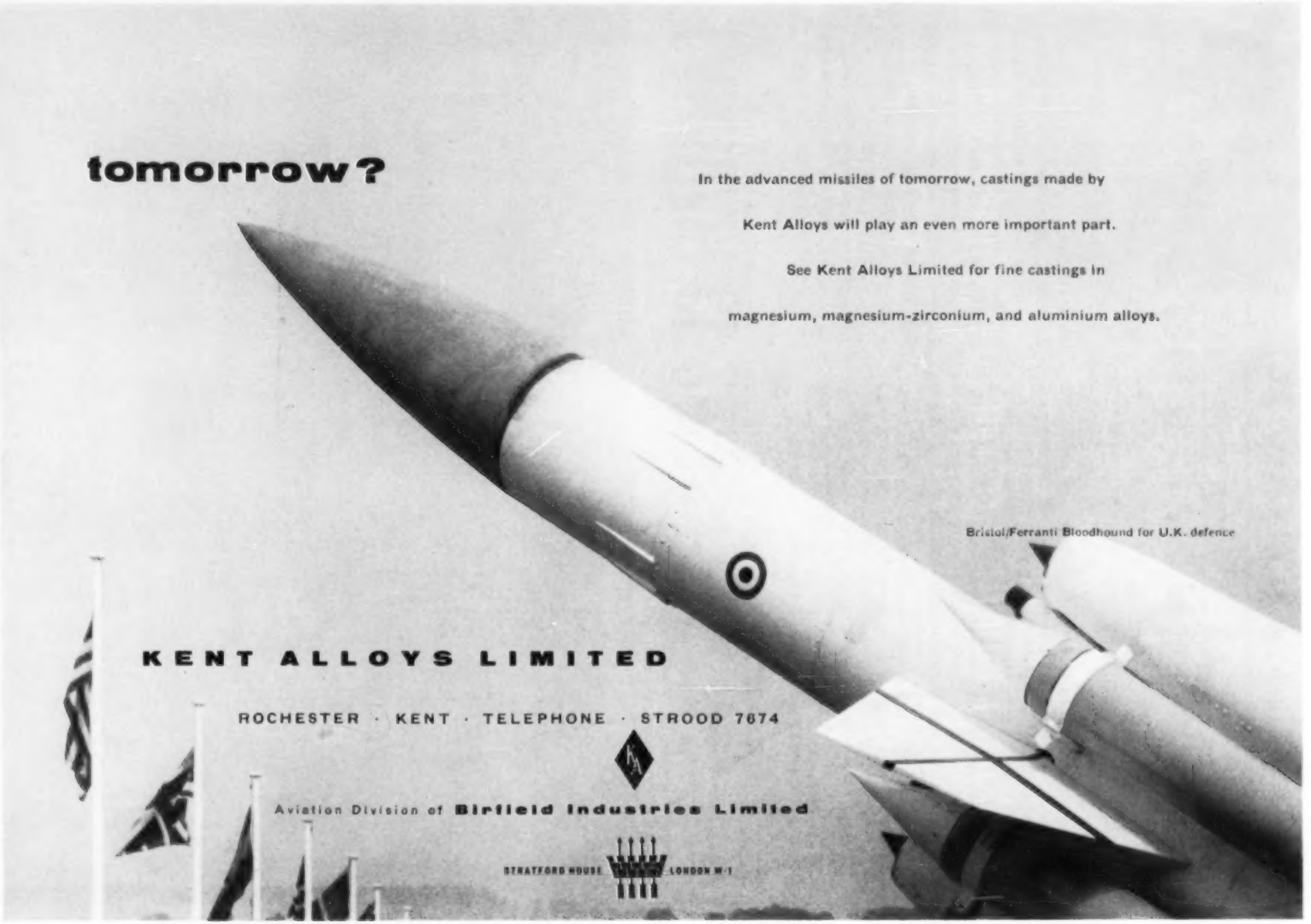

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MISSILES 1958...

a fixed fin. Power is provided by a Pratt and Whitney J57-P-17 providing up to 13,000 lb thrust at sea level. Internal tankage—all within the fuselage—is provided for 21,000 lb of fuel, and 5,000 lb can be accommodated in the toed-in jettisonable underwing tanks. Northrop (Nortronics division) stellar/inertial guidance is used, the automatic computer-assisted tracker being used to monitor the stable platform and compare the desired star positions with the running fixes actually obtained.

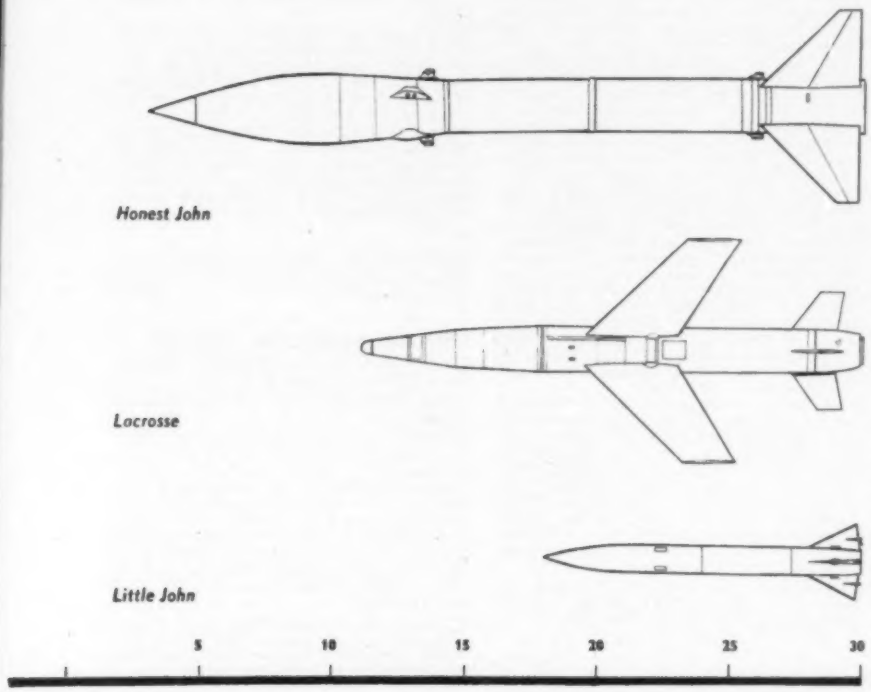
Snark is mounted on a 15-ton, 16-wheel launcher produced by the Erco Division of A.C.F. Industries. On this vehicle is a hydraulically elevating ramp providing zero-length pick-ups for the missile. Boost propulsion is effected by a pair of solid rocket motors, each of 130,000 lb thrust. With the turbojet these give a total launching thrust of 273,000 lb, yet the acceleration is not high enough for problems of control during the four-second boost phase to be ignored. Accordingly initial control is accomplished by jet-deflection rings surrounding the nozzles of the boost motors, actuated by a self-contained system pressurized by the boost cases themselves.

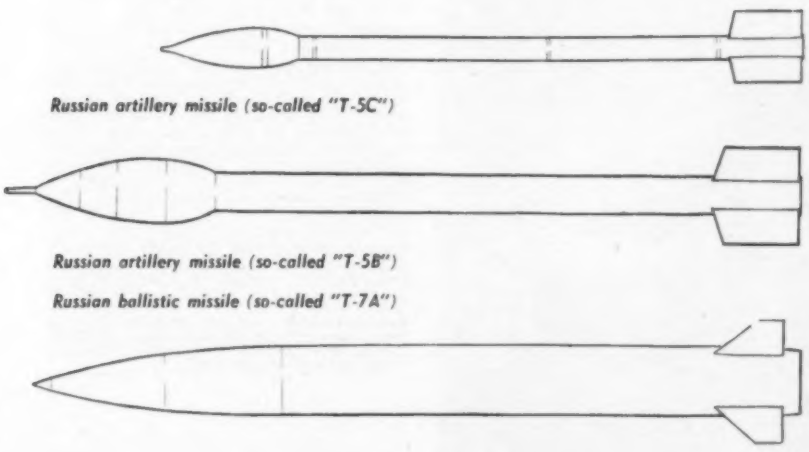
An intake at the base of the fin senses ram pressure. Once the desired impact pressure is reached after fifty seconds of flight this parameter is kept constant, so that the full-power climb is an automatically controlled procedure. As height is gained the climb angle is reduced to maintain the correct ram pressure, until the desired Mach number of 0.93 is reached at the start of the cruise. When the guidance system indicates that the vehicle is at the end of the cruise the Snark is pitched into a pre-programmed zero-g trajectory ending at the target. Bohanan ejectors then separate the entire forward fuselage about one foot ahead of the leading edge, and the remainder of the Snark pitches up again sufficiently violently to suffer structural failure. The nose, with its warhead of up to 20 MT yield (much more than any ballistic weapon), then falls supersonically on to the target.

Snark's flexibility is great. It can approach at tree-top level, has a very small radar cross-section (of vital importance for escaping detection) and can be programmed to take mild evasive action. All portions of the weapon system are air transportable (C-124s are commonly used) and a round can be fired from a very small cleared patch of ground within about an hour of a unit's arrival. Snark squadrons of S.A.C. have 15 missiles and 740 men. The first to be operational is based at Presque Isle, Maine; other units are forming. Squadron costs include the following: fifteen SM-62As, $37.5m; personnel, $2.9m; ground support equipment, $20.3m (including guidance tester $130,000, flight-control tester $123,000, flight-motion simulator $91,000 and launcher $100,000+).

There are reported to be SM-62B and C versions under development, one possibly being a reconnaissance machine. A carrier-based version would also seem logical. Recent official quotations include the following: "Snark has the longest range and greatest accuracy of any missile in the free world today" and "Snark significantly increases the Air Force's current deterrent capability."

SM-62A Snark: overall length, 68ft 10in (75ft 10.5in over the probe); span, 42ft 3in; launching weight, 50,000 lb; cruise speed, Mach 0.93; maximum range, 5,500 n.m (6,333 statute miles).




Russian artillery missile (so-called "T-5C")
Russian artillery missile (so-called "T-5B")
Russian ballistic missile (so-called "T-7A")

SURFACE TO SURFACE

Field of Battle

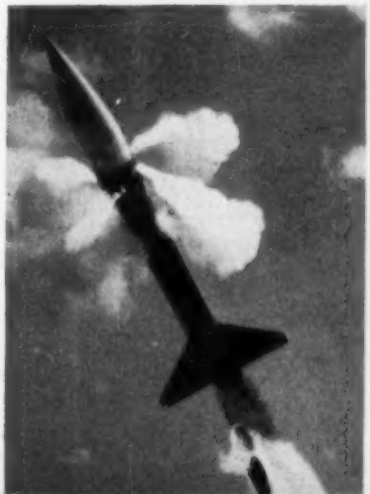
HONEST JOHN

United States Army (soon, the armies of Japan and Western Germany, and probably at least five other Western nations).

Type: Unguided artillery rocket. Drawing on the left.

ALTHOUGH unguided, Honest John deserves mention in this review owing to the fact that many thousands are in world-wide service and a nuclear warhead can be carried. A full history and description was given in our 1957 review. Essentially the weapon comprises a large warhead which can serve a variety of functions—high explosive, nuclear, smoke or special chemicals—propelled by a 23in-diameter solid-propellant rocket motor. Aiming is conducted by carefully adjusting the azimuth and elevation of the launching ramp, and flight stabilization is accomplished by spinning the missile about its longitudinal axis (this spin is energized by tangential rocket nozzles and continued by the four canted fins). The latest development in the system is the Chopper John concept in which complete

Below, a U.S. Army Honest John leaves its launcher. The white smoke plumes behind the warhead come from the four spin motors



Drawn on the previous page and described briefly below, these artillery rockets—the so-called "T-5C"—belong to the Red Army. They are fired remotely from inside the amphibious carrier

rounds and lightweight launchers are air-lifted by H-37 Mojave helicopters.

M31 Honest John: length, 27ft 3in; body diameter, 23in (30in at warhead); fin span, 109in; firing weight, 5,980 lb with 1,500 lb warhead; burn-out speed, Mach 1.7; range, 30,000 yd in a flight time of 87 sec.

LACROSSE

United States Army and Canadian Army; the missile is SSM-A-12.

Type: Guided artillery missile. Drawing: p. 883.

NO other western missile parallels the function of Lacrosse, since this weapon is designed to place a very heavy warhead under command guidance on a battlefield-type target.

As was outlined in our 1957 review, the overall system was originally sponsored by the U.S. Marine Corps, and research and development were conducted by the Cornell Aeronautical Laboratory and the Applied Physics Laboratory of the Johns Hopkins University. C.A.L. are now continuing development and The Martin Company have been responsible for manufacture of a large proportion of the complete system—including the airframe—since 1956.

Of very simple design, the missile comprises a circular-section body of high-strength aluminium alloy, to which can be attached a cruciform of swept wings and a second cruciform, indexed at 45 deg to the first, of movable tail surfaces. Propulsion is provided by a high-impulse solid sustainer by Thiokol, and a variety of warheads, including low-yield nuclear devices, can be carried. Fuzing and arming is accomplished by a G.E. device, and the surrounding nose-cone is by Solar.

Lacrosse is stored and transported in a sprung cradle within a rigid container made by Trailmobile. After unpacking, a crane is used to hoist the completed missile on to a zero-length tubular launcher carried by a 1-ton truck, and the wings and fins are clipped into slots in the body. Guidance is effected by a radio-command system by the Federal Telecommunications Division of I.T. and T. The ground portion of the guidance is broken down into 50-lb packages for hand transport, and includes a miniature gas turbine/alternator set made under a Lear patent by the Propulsion Research Corporation. A forward observer can then fire and control the missile right up to impact, the accuracy being high enough to ensure target destruction with one round. Unstated methods are used to confer all-weather (or apparently, night) ability. It is also reported that the guidance set can be carried aloft in a helicopter.

Production is being handled by Martin's plant at Orlando, Florida. By June of this year 1,000 Lacrosses had been delivered, and an unofficial report states that production is accelerating to "nearly 280 per month." Probable production is of the order of 5,000 rounds. A large number have been fired at White Sands, and in a recent public demonstration the target was a 6ft post (2in × 4in) at a distance of 16,500 yd. The complete system can be air-lifted by the H-37 Mojave.

SSM-A-12 Lacrosse: length, 19ft 2.5in; body diameter, 20.5in; wing span, 9ft; fin span, 4ft 8.5in; firing weight, 5,000 lb; burn-out speed, Mach 2; maximum range, 20 miles.

Now in full service with the U.S. Army, Lacrosse has unerring accuracy and a powerful warhead. Here a Lacrosse crew assemble their weapon; the rear-mounted control fins have yet to be added

LITTLE JOHN

United States Army.

Type: Unguided artillery rocket. Drawing: p. 883.

IT is envisaged that this miniaturized version of Honest John will, in conjunction with Lacrosse, completely replace the earlier weapon. It naturally carries a smaller warhead but is considerably cheaper and far more flexible and mobile on the battlefield.

Propulsion is provided by a solid cast charge by the Allegheny Ballistic Laboratory. Little John airframes are made by Emerson Electric in St. Louis, and the 1,800-lb launcher is produced by Rock Island Arsenal. Production rounds are being evaluated by the 101st Airborne Division, and will shortly be very widely distributed. In good conditions Little John and its launcher can be transported into forward areas by the H-34 Choctaw helicopter; the bigger H-37 Mojave can carry the entire system and its firing crew.

M47 Little John: overall length, 12ft; body diameter, 12.3in; fin span, 33in; firing weight, 980 lb; burn-out speed, Mach 2.6; maximum range, 18,000 yd.

RUSSIAN ARTILLERY MISSILE

Soviet Union (Army); designation unknown but reported unofficially to be T-5B.

Type: Unguided artillery rocket. Drawing: p. 883.

EIGHT examples of this weapon were seen at the 1957 parade through Red Square. Corresponding roughly to Honest John (p. 883), the missile was carried on a JS.3 tank chassis inside an elevating launcher, completely surrounding the missile body, which, in arctic weather, keeps the solid sustainer at the desired firing temperature. Operationally the system is attractive, since the missile is aimed merely by veering the vehicle and selecting the correct ramp elevation (without any of the crew going outside). A nuclear warhead seems possible.

Russian artillery missile: length, about 30ft; diameter, about 30in (warhead) or 18in (motor); firing weight, about 5,000 lb; speed, probably about Mach 2; range, probably 20 miles.

RUSSIAN ARTILLERY MISSILE

Soviet Union (Army); designation unknown but unofficially reported to be T-5C.

Type: Unguided artillery rocket. Drawing: p. 883.

UNLIKE the fatter missile described above, this weapon is carried on the new (1955) amphibious AFV chassis, making for a very mobile and possibly air-transportable combination. The ramp is hydraulically elevated about rear pivots, and seems to be rotatable on a turntable (so that aiming does not involve steering the tracked chassis). Warhead and motor are much slimmer than those of the other artillery rocket and a nuclear charge seems unlikely.

Russian artillery missile: length about 25ft; diameter, about 20in (warhead) or 12in (motor); firing weight, about 3,000 lb; speed, probably about Mach 2; maximum range, probably more than 10 miles.

RUSSIAN BALLISTIC MISSILE

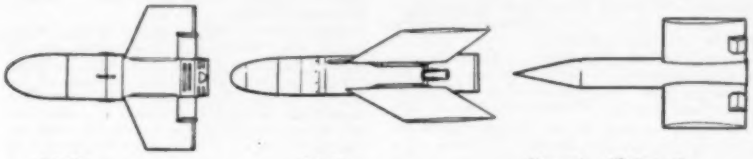
Soviet Union (Army); designation unknown, but unofficially reported to be T-7A.

Type: Guided ballistic missile for tactical use. Drawing: p. 883.

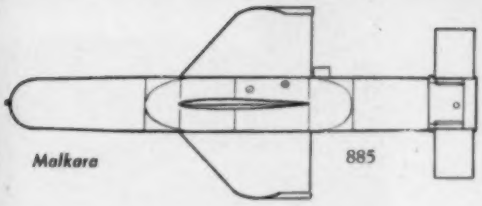
TWO examples of this neat missile were displayed in the Red Square parade in November 1957. It is the most capable missile known which (so far as one can tell) can be fired from an unprepared site without more than one or two minutes' preparation time. It is carried on a pivoted arm on a JS.3 chassis, and for launching the missile all that needs to be done is to elevate the arm to the vertical position. The missile apparently is not left sitting on the ground but leaves from the carrier arm, which may remain attached to the vehicle. There are four tail fins, and a nuclear warhead, solid sustainer and inertial or radio-command guidance seem likely.

Russian ballistic missile: length, about 35ft; diameter, about 40in; firing weight, about 10,000 lb; burn-out speed, probably about Mach 2.5; maximum range, probably about 50 miles.

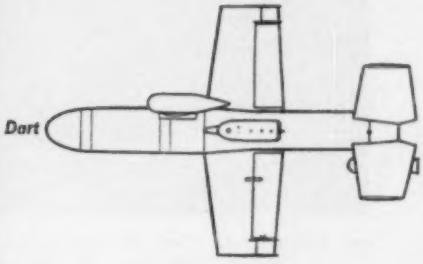
Possibly the smallest guided missile in the world, the Vickers-Armstrongs V.891 is carried in a rigid case which also forms the launcher. A round is here being loaded during field training



S.S.10 *S.S.11* *Mosquito (Cobra 4)*



Malkara 885



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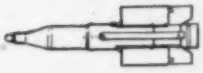
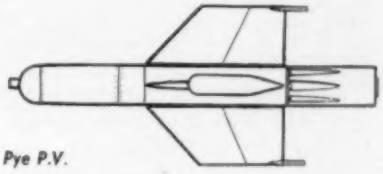


V.891



Pye P.V.

ANTI-TANK

COBRA

Evaluation by Swiss Army and Federal German Army.

Type: Wire guided anti-tank missile for operation by infantry. Drawing: above.

LIKE the majority of the weapons produced jointly by the Swiss companies of Contraves AG. and the Oerlikon Machine Tool Works, Cobra is a private venture. There are two distinct development stages.

Cobra 1 was the first to be fully developed, and this missile originally had the configuration depicted in our 1957 review. A relatively simple cruciform-wing weapon, it was designed for use by infantry and can be transported and operated by one man. The standard pack comprises a rigid box, housing one round in a fully-assembled condition, weighing a total of 32 lb. After unpacking the missile, the operator connects the guidance wires and clips on an underslung boost motor which provides acceleration to the cruise speed of 98 m/sec (190 m.p.h.). Guidance is effected by a conventional optical system, the control box being carried on a strap slung round the operator's neck. An unusual feature is that arming of the 5.5-lb hollow-charge warhead (which can pierce up to 16in of armour) is delayed until the missile is nearing the target. When the missile is beyond the most forward friendly troops the operator can arm it by means of a signal transmitted through a third wire. Cobra 1 is being evaluated by the Federal German Army, and sales and development are largely handled by the Stuttgard firm of Boelkow.

A refined version of this missile is Cobra 4, which has a heavier warhead (7.3 lb) and a guidance system incorporating an ingenious computer to reduce over-correction. Like Cobra 1, Cobra 4 has a cruciform of wings carrying trailing-edge vibrating spoilers. In this it resembles the Nord missiles, but unlike the French weapons Cobra 4 does not roll but is stabilized about the longitudinal axis by a power-driven gyro. Cobra 4 is packed in a rigid container, in which two rounds are stored dismantled. As the photograph on the next page shows, the wings can be clipped on quickly before hooking up the guidance. The external boost is replaced in Cobra 4 by a two-stage internal motor. Production Cobra 4s are being tested by the Swiss Army at Ohsenboden and a version is available for export under the name Mosquito.

Cobra 1: overall length, 30.7in; wing span, 18.9in; body diameter, 3.9in; firing weight, 26.4 lb; flight speed, 190 m.p.h.; effective range, up to 5,900ft.

Cobra 4: overall length, 36.6in; wing span, 23.6in; body diameter, 4.7in; firing weight, 23.2 lb; flight speed, 190 m.p.h.; effective range, up to 6,550ft.

DART

United States Army (development suspended).

Type: Wire-guided missile for use from vehicles against armour or other "hard" surface targets. Drawing: above.

ALTHOUGH it is far from being a complex weapon system, the SSM-A-23 Dart programme was terminated by the Army earlier this year. Other anti-armour systems are being developed. Dart was the responsibility of the Aerophysics Development Corpn., a subsidiary of Curtiss-Wright, and was manufactured at C-W's Utica division. A relatively large missile, it cruised at high speed and carried a heavy hollow-charge warhead. Full details were given in our 1957 review.

SSM-A-23 Dart: overall length, 60in; wing span, 40in; body diameter, 8in; firing weight, 98 lb; flight speed, 600 m.p.h.; maximum effective range, 10,000ft.

FAIREY

British Army.

Type: Guided missile for use against armour or other "hard" surface targets.

PRACTICALLY nothing may be said of this weapon, owing to the fact that it is in a relatively early state of development against an M.o.S. contract. It has been officially announced that it should, when in service, "sweep the heavy tank from the battlefield." The reference to it in the recent annual report of the Fairey Aviation Co., who hold the contract, states that development is continuing steadily.

It is likely that the Fairey weapon will be relatively large, fast and sophisticated, since the small Vickers 891 was once described as "filling a gap in our existing arsenal," and it would be ridiculous to have a plurality of identical weapons under development. An American has suggested that the Fairey missile may be comparable to the Pye P.V. (overleaf).

MALKARA

Australian Army and British Ministry of Supply.

Type: Command-guided missile for operation against heavy armour and all other major battlefield targets. Drawing: above.

MALKARA is the first guided weapon to be developed in the Commonwealth of Australia. The decision to concentrate on this weapon was taken in 1951, engineering development being handled by the Government Aircraft Factory, with key scientific personnel provided from the Aeronautical Research Laboratories of the Department of Supply.

In its essentials, the configuration of Malkara strongly resembles that of the Short SX-A5 (p. 891). It comprises a body over 6ft long, carrying detachable fixed tail fins and a detachable cruciform of moving wings, the body in line with the latter being brought out to a square section to improve airflow around the wing roots during manœuvre; propulsion is provided by internal solid-propellant boost and sustainer charges. Malkara is designed to carry a large shaped-charge warhead weighing between 50 and 60 lb. It is fired from a zero-length launcher mounted on any light vehicle, and is directed to its target by electronic signals transmitted from the control post (the actual method involved is secret, but obviously does not involve wires).

After a period of general study and preliminary experiments, the form of the weapon and its control system was determined early in 1954, and trials of fully controlled rounds began at Woomera in November 1955. During extensive flight-testing Malkara has shown itself almost 100-per-cent accurate. From the inception of the project the United Kingdom has collaborated closely, and the British Ministry of Supply has ordered 150 rounds for field evaluation and troop familiarization which are at present being tested on the range in Kircudbright, Scotland. The striking power of Malkara is exceptional, and should be sufficient to despatch any tank at the first shot. It is noteworthy that the airframe, propulsion unit, guidance system and warhead are all of Australian design and manufacture, and a simulator for training operators has also been evolved.

Malkara: overall length, 78in; wing span, 32in; firing weight, approximately 200 lb; flight speed, approximately 400ft/sec (273 m.p.h.); effective range, more than 6,000ft has been achieved by experimental rounds and this could be considerably increased if required.

Now more generally known under the name of Mosquito, the Cobra 4 is a development by the Swiss Contraves-Oerlikon team. The box holds two rounds, which are assembled for firing

"P.V."

Private venture by British company.

Type: Wire-guided missile for use against armour and other "hard" ground targets. Drawing: p. 885.

THIS essentially simple weapon system is unusual in that it is a private venture by a company with no previous experience of the design and manufacture of flying vehicles. This may prove to be an advantage, since the electronic aspects of the work are generally among the most difficult and Pye are renowned for their prowess in this sphere.

In size the Pye P.V. weapon surpasses that of all other anti-tank missiles currently under development, with the exception of the Australian Malkara (and possibly of the Fairey, although nothing is known publicly of the latter). Nevertheless, Pye have gone to great lengths to make the entire system transportable by one man, and it is also amenable to carriage by helicopters. The cylindrical body carries a large shaped charge on its nose and a fixed cruciform of wrapped-sheet wings; two of the wings carry flares and the other pair mount streamlined nacelles for the guidance wires. The two-stage solid-propellant internal motor is produced by Bristol Aircraft, and the missile is steered by deflection of the jet. The complete weapon system comprises the missile, a simple tubular launcher, and a 20-lb control box which contains power supplies, ground shaping unit and transmitter. Flight trials are now in progress at an M.o.S. range.

Pye P.V.: overall length, 60in; wing span, 24in; body diameter, 6in; firing weight, 80 lb; flight speed and maximum effective range, classified.

S.S.10

Armies of France, U.S.A., Israel, Sweden, Federal Germany and probably other countries.

Type: Wire-guided missile for use against armour or other surface targets; launched chiefly from the ground by infantry, although vehicles and slow-flying aircraft have been used. Drawing: p. 885.

A DESCRIPTION of this diminutive missile and its weapon-system equipment was published in our issue of February 7 of this year. Evolved originally from German concepts of 1943-45, this missile has been designed and developed by Nord-Aviation S.N.C.A. as the Nord 5203. It comprises a cylindrical body containing a solid rocket motor (the first portion of which burns at relatively high thrust to act as a boost stage), to which are attached four identical wings and a hollow-charge warhead. Control signals are sent through thin wires from a miniature joystick-type command-set at the point of launching, the operator controlling the S.S.10 on a visual line-of-sight path. The signals govern the motion of vibrating spoilers on the trailing edges of the wings, which produce asymmetric drag for steering.

Several thousand rounds have now been produced. Current production is stated to be at least 500 per month, and the complete system is thoroughly proven—including actual combat, when it was instrumental in enabling the Israeli army to defeat Egyptian armour in 1956. For training purposes an inert warhead can be used, but the normal operational warhead is an 11-lb hollow charge which can penetrate 16in of armour when impacting perpendicularly.

S.S.10: length, 33.85in; span, 29.52in; body diameter, 6.5in; firing weight, 33 lb; warhead weight, 9 lb; flight speed, about 180 m.p.h.; maximum range, 5,000ft.

S.S.11

French Army, French Navy and (evaluation quantity) the British Ministry of Supply; later the S.S.11 is likely to be used by most NATO nations and other countries.

Type: Wire-guided tactical missile for use against armour or other surface targets; launched from the ground, from vehicles or slow-flying aircraft. Drawing: p. 885.

DETAILS of this missile system, made by Nord-Aviation as the Model 5210, were contained in our issue dated November 14 of this year. Compared wth its predecessor (S.S.10, below) the S.S.11 is much faster, heavier and longer-ranged. It is designed to supplement, rather than replace, the S.S.10, and is intended for operation chiefly from vehicles, light aircraft, helicopters or small naval craft rather than by infantry.

Owing to the much higher performance, the vibrating-spoiler control system which works so well on S.S.10 has been replaced by the jet-deflection control which was proved on the Nord 5103 air-to-air missile (*q.v.*). After firing, the missile spins slowly about its longitudinal axis to cancel out airframe and motor manufacturing inaccuracies, thus greatly reducing tooling and production costs; this spin is imparted by the incidence of the four sandwich-type wings. Boost propulsion is effected by the high-thrust portion of the solid internal charge which burns first (through lateral nozzles), leaving the long-burning, low-thrust portion to act as the sustainer. The latter exhausts through a nozzle in the centre of the base of the body and the direction of its jet is modified by an interrupter, or deflector, system to control the flight of the missile.

Twin guidance wires, paid out from two canisters above and below the sustainer nozzle, transmit signals from the firing point, where will be found a binocular sight, power pack, signal generator and a miniature joystick control unit. Various types of warhead can be fitted, but the most common operational head is a hollow charge, weighing 13 lb, which can punch through 19.7in of typical armour when impacting perpendicularly. S.S.11s can be launched from aircraft travelling at up to 250 m.p.h., and a trials batch are being evaluated by the M.o.S. from Twin Pioneer aircraft.

S.S.11: length, 42.5in; span, 18.7in; body diameter, 6.5in; firing weight, 62 lb; warhead weight, 13 lb; flight speed, 425 m.p.h.; maximum range, 11,500ft.

V.891

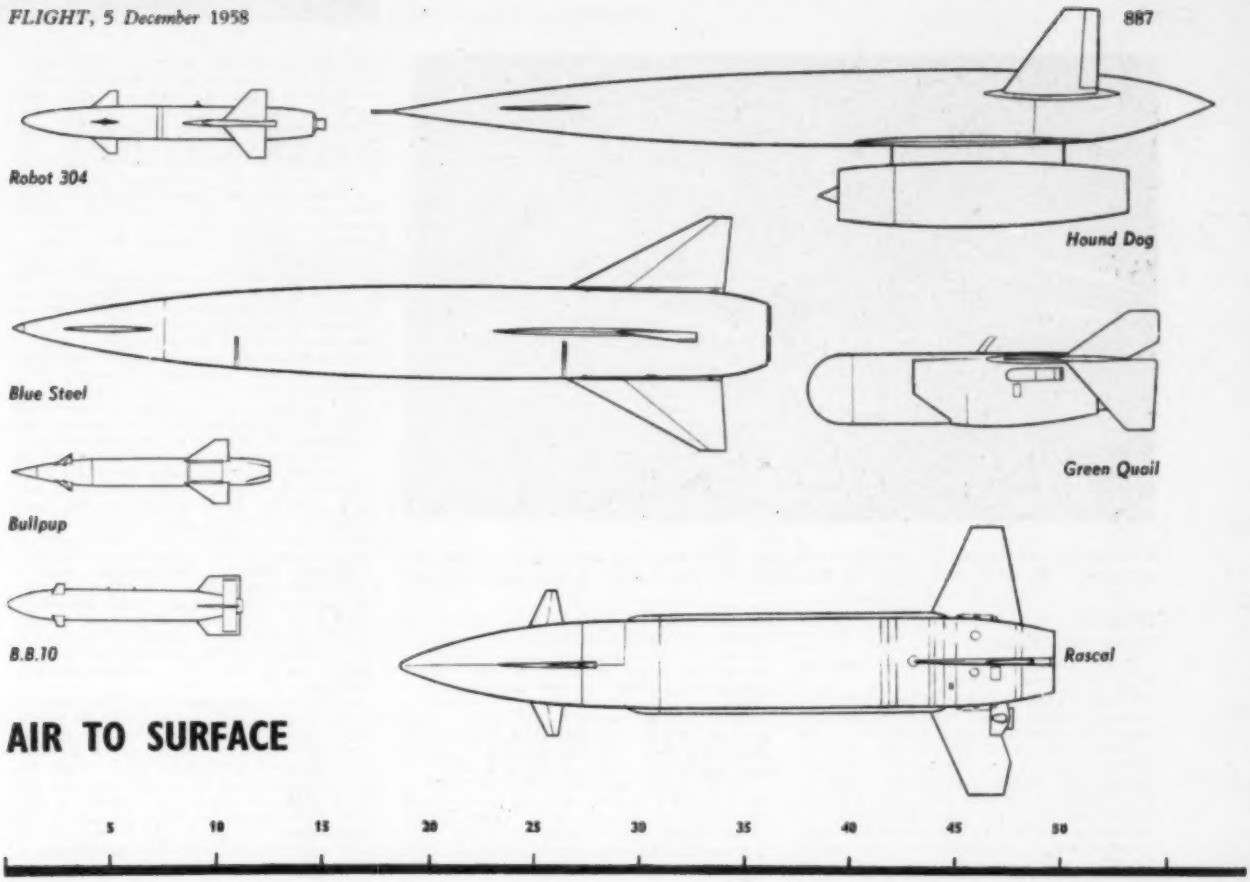
Private venture by British company.

Type: Small wire-guided missile for use against armour or other "hard" targets. Drawing: p. 885.

POSSIBLY the smallest guided missile in the world, the V.891 has been developed by Vickers-Armstrongs (Aircraft), Ltd., at Weybridge to meet all the requirements of the British Army. The missile is packed in a completely assembled condition in a rigid box which, when opened, can be used to form the launcher. Like most of these weapons, the vehicle portion has a cruciform of wings, and, in order to reduce the risk of hitting obstacles during flight, the span has been reduced to the almost incredibly low value of 11in. Propulsion is effected by a two-stage solid sustainer, and control is accomplished by a simple optical sight and thumb-button, no computer being incorporated. The missile's flight is controlled by four surfaces hinged to the trailing edges of the wings, the airborne guidance packages being housed in plastic fairings along the sides of the body. The hollow-charge warhead is of a new design, triggered by a nose probe which is extended when the missile is launched. The weapon in its container weighs about 40 lb.

V.891: length (with probe retracted), 33in; body diameter, 4.5in; span, 11in; firing weight, considerably under 40 lb; flight speed and effective range, classified.

As outlined above, the British electronics firm of Pye, Ltd., are developing this complete weapon system as a private venture. The principle of operation is clearly shown in this photograph



B.B.10

French Air Force.

Type: Rocket-propelled guided bomb. Drawing: above.

VERY little new information has become available on this weapon since it was described in our 1957 review. Developed principally as part of the weapon system of the Vautour, the B.B.10 carries a warhead of about 400 lb and is guided by radio command from the launching aircraft. A small camera is fitted in the extreme nose of the missile and this almost certainly transmits a television picture of the target to a screen in front of the controller, who can then steer the weapon through a radio system governing the cruciform of fins on the forebody. A unique feature among modern weapons is the annular fin joining the four stabilizing fins at the rear. The B.B.10 has a solid sustainer.

B.B.10: length, approximately 11ft; span of rear fins, approximately 32in; launching weight, approximately 900 lb.

BLUE STEEL

Royal Air Force (Bomber Command).

Type: Supersonic cruise-type, air-to-surface vehicle capable of carrying a thermonuclear warhead; an alternative description is "stand-off bomb." Drawing: above.

UNOFFICIALLY reported—by an American writer—to bear the code-name given above, the air-to-surface missile for Bomber Command is being developed by the Weapons Research Division of A. V. Roe and Company, Ltd., at Woodford, Cheshire. Internal details, performance and propulsion remain classified, but it is possible to comment on the external configuration. At the S.B.A.C. Flying Display three months ago a yellow-painted full-scale test vehicle carried by a Vulcan was briefly demonstrated and a small model of the weapon and a larger CTV (control test vehicle) were displayed statically.

Overall length of the circular-section fuselarge is approximately 35ft. The nose is pointed and ogival, and the tail tapers in planform only, resulting in a stern which lends credence to the report that the powerplant is a de Havilland Double Spectre rocket engine. The Double Spectre runs on high-test peroxide and kerosine and has two superimposed chambers—each presumably with a higher rating than the 7,000 lb-thrust of earlier Spectres—one of the chambers having a fixed thrust for cruise propulsion and the other being fully variable. If the Double Spectre is, in fact, the powerplant of Blue Steel it would confer exceptional altitude capability and supersonic cruise performance.

No details of the structure may be published, but it is pertinent to recall that Avro conducted extensive research into brazed-steel-sandwich airframes for the Avro 730 and a completely Redux-bonded structure for the Avro 720. Aerodynamic surfaces on the missile appear to comprise interlinked delta foreplanes for control in the pitching plane, a rear-mounted delta wing with small inboard ailerons, and upper and lower stabilizing fins. The lower fin is designed to hinge to port to provide ground clearance, and the wing-tips have sharp anhedral (to clear the inboard jet pipes of the Victor bomber).

According to an official of A. V. Roe at the Weapons Research Establishment at Woomera, South Australia, his company's missile is scheduled to be intensively tested at the W.R.E. throughout the coming year, using a Vulcan as the carrier. Prototypes have been flying for some months and actual launchings from a Vickers Valiant are reported to be in progress at Woomera. In service, Blue Steel will be carried only by the Vulcan and Victor (Mks 1 and 2) and aircraft already delivered are likely to be modified to permit them to accommodate the missile. Each will carry one, partially submerged in the bomb bay. The performance figures given in the next column were quoted in Adelaide last August by the Avro official already mentioned.

Blue Steel: overall length approximately 36ft; wing span, approximately 16ft; launching weight, probably about 15,000 lb; flight speed, supersonic; design range stated to be 400 miles.

BULLPUP

United States Navy and Marine Corps; the missile is designated ASM-N-7.

Type: Tactical guided weapon for firing from carrier-based aircraft. Drawing: above.

PROBABLY the simplest guided-weapon system in American service, Bullpup is produced at the Orlando, Fla., division of The Martin Company. The circular-section body of the missile houses any of a variety of non-nuclear 250-lb warheads, as well as a solid motor. The missile is controlled by a cruciform of delta foreplanes and stabilized by a rear wing cruciform. After firing the missile, the pilot of the carrier aircraft tracks it visually through his gunsight and imparts left/right and up/down commands by radio link.

There appear to be two variations on this guidance. One is a system whereby the missile is controlled by the control column of the carrier aircraft (although the latter obviously manœuvres by twist-and-steer); the other is said to be an aural system—obviously not yet operational, and probably a myth—in which the missile responds to a list of spoken commands or other sounds. Be that as it may, Bullpup is intended to enable small aircraft to stand-off from heavily defended targets and still achieve accurate strikes. Output is unofficially claimed to be rising to 600 monthly, and the price is said to be $5,000, with $4,000 in prospect. Rounds are stored dismantled; parts can be taken from store after several months, clipped together and loaded on to an aircraft by three men in five minutes. It is said that maintenance and training requirements are virtually non-existent. A development is White Lance (p. 889).

ASM-N-7 Bullpup: length, 11ft 2in; body diameter, 12in; wing span, 43in; firing weight, 540 to 585 lb; flight speed, Mach 1.8; effective range, up to five miles in clear visibility.

Air-launched countermeasures vehicles can be made quite small; yet the GAM-72 Green Quail can present the same radar picture as the big B-52F, from which it is here being launched

CORVUS

United States Navy.

Type: Multi-purpose vehicle for launching from carrier-based aircraft.

PROGENITOR of an entire "crow family" of weapons (corvus is the Latin for the bird), this weapon is much the largest home-grown project ever tackled by Temco Aircraft, of Dallas, Texas. Temco's first Corvus contract was a preliminary design-development award of $16m made in January 1957, and a further $6.5m contract for continued development was announced at a later date. Temco is the Corvus system-manager, responsibile for the missile, aircraft modification, ground handling and test equipment. The company's work on the missile is centred at the plant at Garland, Texas.

It is officially stated that Corvus is a high-performance, stand-off missile which will enable carrier-based aircraft to attack heavily defended targets. Temco said it represents "a sophisticated weapon system based upon advanced technological developments." Sub-contracts awarded by Temco include R.M.I. Division of Thiokol (powerplants) and W. L. Maxson Corp. and Texas Instruments (guidance). Unofficially it is said that Corvus will cruise supersonically for more than 50 miles and, in one form, be intended for homing on to all enemy sources of electro-magnetic radiation. In the latter rôle Corvus would be a countermeasures device. Carrier vehicles already named include the Grumman A2F-1, Martin P6M-2 and N.A.A. A3J-1.

CROSSBOW

United States Air Force (the missile is designated Guided Air Missile 67).

Type: Air-to-surface countermeasures and attack vehicle.

LITTLE is known of this missile except for the fact that it is powered by a turbojet—originally a Westinghouse J81 but now probably to be either a J83, J85 or Pratt and Whitney J-12—and that it is designed to home on to enemy surface-sited radars. In this rôle it thus becomes a countermeasures vehicle, capable of reducing the effectiveness of the enemy's electronic environment. It has been unofficially stated that Crossbow cruises at about 500 kt. Prime contractor is Radioplane, a Division of Northrop Aircraft, Inc.

GREEN QUAIL

United States Air Force (Strategic Air Command); the missile is designated GAM-72.

Type: Air-launched countermeasures vehicle for decoy and diversionary functions over enemy territory. Drawing: p. 887.

DURING the past three years in particular, the science of countermeasures has become one of extreme sophistication and complexity. Truly startling results can now be achieved, and the increased chance of survival which an e.c.m. (electronic countermeasures) vehicle can afford a S.A.C. bomber more than outweighs the cost of developing it. The GAM-72 Green Quail is the first such device to be designed for air launching, and it should be capable of being taken into enemy air-space by any S.A.C. aeroplane.

Green Quail—the name could fit into the British coding system—is under development by McDonnell Aircraft. It is a small, stubby, delta-winged vehicle, fabricated wholly from a glass-fibre material (to reduce the minimum radar cross-section) and powered by a G.E. J85 turbojet of some 2,500 lb thrust. Powerful e.c.m. systems, largely by Ramo-Wooldridge, are said to be carried in the nose, and Summers Gyroscope is named as a guidance contractor (guidance would presumably be by a pre-programmed autopilot or radio command). GAM-72 is almost certainly non-recoverable, and presumably destroys itself when its task is accomplished. (According to *Aviation Week* the programme has slipped six months through the inability of G.E. to deliver an engine, although the J85 completed a 15-hr qualifying test at Lynn in August and is now flying in the T-39 Sabreliner.)

HOUND DOG

United States Air Force (Strategic Air Command); the missile is GAM-77 and it forms part of weapon systems WS-131B and WS-132A.

Type: Supersonic-cruise, winged, air-breathing vehicle for launching from a strategic bomber to accomplish delivery of a nuclear warhead (WS-131B) or to facilitate countermeasures (WS-132A). Drawing: p. 887.

MORE money has been spent by the U.S. government on the Boeing B-52 family of strategic bombers than on the manufacture of any other weapon (not excluding World War 2). The GAM-77 Hound Dog missile is a most valuable adjunct to the great bomber, and it is intended to keep the B-52 competitive at least up to 1963, when the B-70 Valkyrie should become operational.

Originally GAM-77 was projected solely to fulfil one mission: to carry all types of warhead, including the largest thermonuclears with yields of up to about 20 MT, to targets known to be so well defended as to make the task of a B-52 with ballistic bombs extremely hazardous. Last year, after an intense competition, the contract was awarded to the Missile Development Division of North American Aviation, at Downey, Cal., coming as a welcome pick-me-up shortly after cancellation of that division's vast WS-104 Navaho programme.

In fact, the airframe chosen is very similar to that of the X-10 test vehicle, one of the first used in the WS-104 flight-test programme (and, in 1953, the fastest air-breather in the world, with a cruising speed of more than Mach 2). The X-10 had two engines (initially Westinghouse J40s), but GAM-77 has only one, and this necessitated relocation. The configuration is classified, but a fair amount has been revealed in the American technical Press.

Chosen engine for "initial propulsion" is the Pratt and Whitney J52, a two-spool turbojet rather like a scaled-down J57. This choice is curious, since ramjet propulsion would seem to offer a higher performance for the same range. Dry thrust of the J52 is 7,500 lb, and in the GAM-77 it apparently does not have an afterburner. Secondary propulsion may be used to increase thrust during evasive action or in the final dive. The J52 power package is carried beneath the missile body on a pylon containing monitoring and launching equipment. For increased pressure-recovery the engine inlet is of the variable-geometry type (not necessarily of the centre-body configuration assumed by our artist in the drawing on the previous page).

Airframe construction undoubtedly involves a great deal of metal-bonding, chemical milling (pioneered by N.A.A) and heat-resistant sandwich. Like the X-10, Hound Dog may have foreplanes to control pitch, elevons on the rear-mounted cropped-delta wing and a butterfly-type vee tail. Guidance, by N.A.A.'s Autonetics Division, undoubtedly involves inertial elements, although subsidiary monitoring systems (star-tracking, radar eommand, doppler or terrain-examination) would be logical. The guidance carried in the missile may well be modular, so that units may be plugged in to suit the particular mission involved.

On most missions the Hound Dog is to be carried by the B-52G, which can lift one missile under each wing (the weapon can also be carried by the B-58 Hustler and—it is said—by the Navy's McDonnell F4H). Both the B-52's Hound Dogs can be fired together and left to ferret out two widely separated targets simultaneously. In the WS-132A mission the Hound Dog will apparently be required to carry a payload of electronic countermeasures, and used as an air-launched source of a friendly electronic environment, doubtless on a larger scale than is possible with Green Quail (*q.v.*).

It should not be long before flight-testing is announced as being in progress. The first complete guidance and flight control system is reported to have been delivered from Autonetics last September, and Boeing engineers have been undergoing 10-day integration sessions since the same month. Fiscal year 1959 provides $139m for the missile (an increase of $48m on the original appropriation, but still below Senator Jackson's recent cry for $205.6m). The first production contract, for $18.9m, was placed last month and delivery to S.A.C. squadrons is scheduled for the calendar year 1960.

GAM-77 Hound Dog: overall length, approximately 40ft; wing span, approximately 14ft; launching weight, about 12,000 lb; cruising speed, supersonic (probably about Mach 1.6); maximum range, approximately 350 miles.

RASCAL

United States Air Force (Strategic Air Command); the missile is designated GAM-63.

Type: Air-launched, rocket-propelled weapon for attacking strategic targets. Drawing: p. 887.

IN 1946 the Bell Aircraft Corporation were awarded a study contract for a rocket-propelled pilotless vehicle capable of carrying a nuclear warhead from a manned bomber to a priority target. It was at this date that the U.S. Air Force first appreciated that even the then-forthcoming generation of jet bombers might be unable to penetrate to a well-defended target in order to deliver free-falling weapons. Bell accordingly developed a test vehicle named Shrike, and this programme was completed in 1953. This led to the Rascal missile, for which Bell—as prime contractor—were assigned responsibility for the missile, ground support equipment, training aids and conversion of the B-47s of Strategic Air Command into the DB-47 configuration.

Originally known as XB-63, Rascal was later redesignated GAM-63A (guided air missile); it is the Bell Model 66. Aerodynamically is it a canard, with cruciform wings and con-

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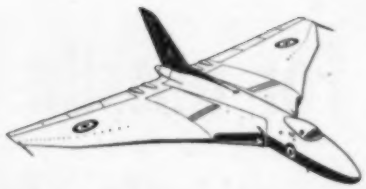

No. 3 in a series of paintings by Keith Shackleton S.Av.A. presented by Cellon Limited

Pintails in the Snow

The picture shows two drake pintails, one of the most beautiful and fastest-flying of the waterfowl. It is a bird which is common in Britain and breeds here, though its range extends all across Europe, Asia and North America.

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trol surfaces, comprising upper and lower nose rudders, a fixed foreplane with elevators, a rear-mounted wing fitted with ailerons, and upper and lower rear fins which fold sideways to facilitate ground handling and stowage on the carrier aircraft. Propulsion is provided by a Bell rocket motor with three superimposed aluminium-alloy chambers operating on fuming nitric acid and JP-4 fuel. A variety of warheads, some with a very high yield, can be accommodated within the fuselage. Varying types of guidance have been employed during the launching, cruise and terminal portions of the flight. The production GAM-63A has inertial guidance by Bell Aircraft Avionics Division; previously radio-command had been dominant, system-contractors including Federal Telecommunications Laboratory and R.C.A.

About 40 GAM-63s were launched from B-36s and B-47s during the research and development flight-test programme from Holloman A.F.B. in Mexico, which was completed in 1957. By this time Rascal was in production, and the first inventory missile was accepted at Eglin A.F.B. on October 30, 1957. The complete weapon system was assigned to operational status the following month. Production at Bell's Niagara Frontier Division is now almost complete. Several Rascals launched from DB-47s have achieved hits within a circle of 1,500ft radius. Chief item of ground equipment is the combined transporter/lifter vehicle, which is produced by the Lull Manufacturing Co.; other support items are manufactured by Bell and American Machine and Foundry Co.

GAM-63A Rascal: overall length, 31ft 11.5in; span of wings, 16ft 8.5in; span of foreplanes, 11ft 5.4in; body diameter, 48in; launching weight, about 13,500 lb; full-load ceiling, 85,000ft; maximum speed (possibly also the cruising speed), about Mach 1.5 or 1,000 m.p.h.; range, about 75 miles.

RAVEN

United States Navy (and, presumably, Marine Corps).

Type: Relatively simple missile for use by carrier-based aircraft.

FROM its name it would be logical to place this missile in the Corvus family (*q.v.*), although it is also described as being a more sophisticated successor to Bullpup (*q.v.*). A new aircraft is stated to be designed around this weapon, although this seems to be a *volte face* state of affairs.

ROBOT 304

Royal Swedish Air Force (Attack Wings F-6, 7, 14 and 17).

Type: Subsonic vehicle for launching from high-speed strike aircraft. Drawing: p. 887.

LITTLE additional information has become available on Robot 304 since its existence was disclosed one year ago. The requirement was established in the autumn of 1949; project work began in March 1950 and the first test round was launched on February 11, 1955. The Robotbyran state that "a considerable number" of test firings have taken place since.

All-weather guidance is fitted (implying a system more sophisticated than simple radio-command according to visual tracking), and the flight of the weapon is controlled through the cruciform of fins mounted on the fore-body. Lift is provided by a delta wing, which has large fixed fins at its tips. The 304 is clearly large enough to carry a nuclear warhead and the weapon has been officially described as the best available to the R.S.A.F. In service its principal carrier will be the Saab A-32A Lansen, which can carry one of these missiles beneath each wing.

Robot 304: overall length (including projecting sustainer nozzle); 14ft 9in; wing span (including tracking-flare nacelles), 6ft 8in; span of control cruciform, 37in; body diameter, 19.4in; launching weight, probably about 1,200 lb; flight speed, high-subsonic; effective range, several miles.

WAGTAIL

United States Air Force.

Type: Air-to-surface missile for supersonic launching.

SECURITY withholds publication of any official details of this remarkable weapon system, which is being developed under the management of the Minneapolis-Honeywell Aeronautical Division. Early last year this company received a contract for $500,000 from the Air Force Armament Center covering design, mock-ups, tunnel tests and evaluation at Eglin A.F.B. This study contract is in hand at the Minneapolis-Honeywell missile control centre in Los Angeles. The basic vehicle will have a simple gyro-reference guidance system and a warhead developed by the Honeywell Ordnance Division. The Wagtail has been successfully sled-tested.

An unofficial report has stated that Wagtail will have forward-firing rockets to reduce its speed to a very low value before the ignition of the solid sustainer. By this means the weapon would be capable of being released at ground level at Mach 2, and would thereafter slow up and follow the contours of the terrain while the carrier aircraft made its escape at undiminished speed.

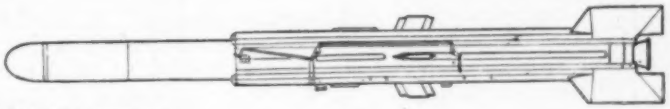
WHITE LANCE

United States Air Force (Tactical Air Command).

Type: Relatively simple guided missile for tactical use.

LIKEWISE a product of Martin's Orlando plant, White Lance is said to be a rather more advanced version of Bullpup, tailored to meet the needs of the Air Force. It is probably somewhat larger than the Navy's weapon, since a choice of high-explosive or nuclear warheads is mentioned.

ANTI-SUBMARINE



Rat (A.S.W. weapon)

ASROC

United States Navy.

Type: A.S.W. missile for launching from surface craft.

PRIME contractor for this weapon system is the Minneapolis-Honeywell Regulator Co., Ordnance Division. Asroc is reported to signify Anti-Submarine ROCket, and the vehicle part of the system is certainly rocket-propelled. According to *Missiles and Rockets*, it is designed for launching from underwater, but this has not yet been confirmed. Most of Asroc's flight takes place in the atmosphere.

RAT

United States Navy.

Type: Rocket-propelled torpedo system.

LOOKED at in retrospect, it appears that Rat will prove to have ushered in a completely new family of weapon systems combining the techniques of the classic torpedo with those of airborne vehicles. Conceived at the Naval Ordnance Test Station at China Lake, Cal., Rat is in production at the Allegany Ballistics Laboratory, Cumberland, Md. It consists of a standard homing torpedo attached to a jettisonable airframe incorporating stabilizing surfaces and a solid-propellant rocket motor.

Altogether, the Rat system consists of search and detection equipment, a fire-control system, a launcher and a missile. In the majority of U.S. Navy destroyers, Rat can be launched by modifying the existing 5in gun mounts, and the search and fire-control systems already installed require only minor modification. In current installations Rat is normally launched at between 30 and 40 deg elevation. After burnout, the rocket drops away and the missile continues on the programmed trajectory. It then dep'oys a parachute which stabilizes its flight and restricts the speed of entry to the water so that the nose-cap and guidance system are undamaged. On entry to the water the torpedo releases its parachute and nose-cap, and thereafter behaves as a standard homing torpedo.

Rat: overall length, 13ft 6in; body diameter, approximately 15in; firing weight, 480 lb; effective range, 5 miles.

SUBROC

United States Navy.

Type: Underwater/air/underwater or air/underwater missile.

SINCE early this year the U.S. Navy has been intensively examining the possibilities of this difficult weapon system, which is intended for the destruction of submarines. Carrying a nuclear warhead, it can be launched through a torpedo tube of a submarine or surface vessel; it flies between 25 and 50 miles through the air and then re-enters the water and homes on to its target.

In April the director of the long-range objectives group of the Office of the Chief of Naval Operations stated that the key to the Subroc system was to increase the range of sonar equipment. It is known that such a system can, in fact, be programmed with some assurance of success. Following an intense competition involving fourteen major companies, the Bureau of Ordnance awarded a $65m development contract to Goodyear Aircraft Corporation, Akron, Ohio, late in June. Goodyear are prime contractors for the weapon system, including production and tooling methods, and they are working in close collaboration with the Naval Ordnance Laboratory at Silver Spring, Md. Chief sub-contractors are Librascope division of G.P.L. and Kearfott.

It is hoped to perfect a sonar system, carried by the Subroc-armed submarine, capable of detecting enemy submarines at the maximum range of the missile. The Subroc weapon system would include the detection equipment and a target-course computer. The vehicular part will almost certainly be rocket-propelled, both underwater and in the air, and the final dive will be a ballistic trajectory.

SURFACE TO AIR

BLOODHOUND

Royal Air Force (Fighter Command) and Royal Swedish Air Force.

Type: Semi-active homing weapon system for area defence from fixed bases. Drawing: opposite.

SINCE July 1957 this lethal weapon system has been gradually becoming operational with Fighter Command; and, as was reported in our issue of November 7, "the stage has now been reached where, although trials are still under way, the station could go on permanent watch and become operational overnight." Except possibly in the Soviet Union, there is no other homing anti-aircraft missile system in full operation from a land base.

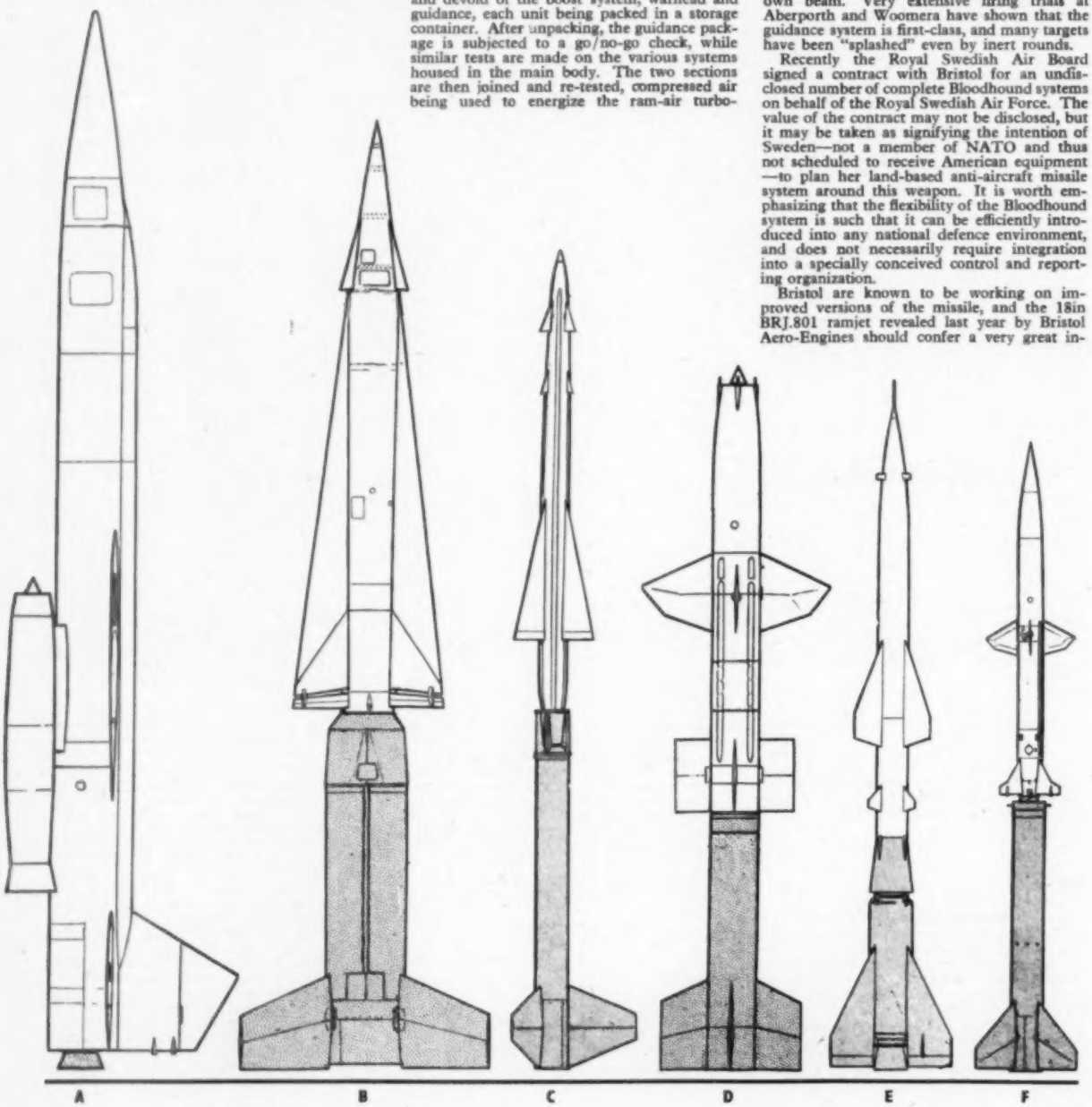
Originally known by its code-name of Red Duster, the Bloodhound weapon system has been evolved jointly by Bristol Aircraft and Ferranti; major sub-contractors include M.L. Aviation (ground-support equipment); E.M.I. Electronics and Decca Radar. Although highly efficient, the vehicle has an unusual configuration. An account of its evolution was published in our issue of November 14. Most of the structure is manufactured in light alloy according to traditional aircraft principles. Cruise propulsion is provided by a pair of 16in Bristol Thor ramjets mounted above and below the circular-section body. The latter houses the kerosine fuel, an exceedingly large warhead system (Bloodhound will eventually have a nuclear head) and the airborne portion of the guidance system, the receiver dish and its mechanism being housed beneath a pointed ogival radome. Aerodynamically the configuration is unique; twist-and-steer manœuvrability is provided by the sharply tapered wings which can pivot differentially or together, and flight stability is assisted by a fixed slab tailplane.

Rounds are received from Bristol's factory at Cardiff with blanking plates over the motors and devoid of the boost system, warhead and guidance, each unit being packed in a storage container. After unpacking, the guidance package is subjected to a go/no-go check, while similar tests are made on the various systems housed in the main body. The two sections are then joined and re-tested, compressed air being used to energize the ram-air turbo-pumps which drive the fuel and hydraulic systems. A gantry places the accepted round on the launcher-loading trolley, which is then towed to the explosives area for the addition of the warheads and the boost system. The boost system comprises four wrap-around motors, with large stabilizing fins, pivoted to a common anchorage at their rear ends and jettisoned as a unit. Finally the boosted round is slid off its trolley on to the zero-length launcher, which can rotate in azimuth but is always set at an elevation of 45 deg for firing.

In the fire-unit area the launchers are quite widely distributed and all essential supplies come through underground conduits. Each SAGW (surface-to-air guided weapon) Wing is equipped with an exceedingly powerful three-dimensional tactical radar by Metropolitan-Vickers, which has a very high data rate combined with a tracking system and computer store. Each of the wing's fire-units is equipped with a B.T.H. semi-automatic target-illuminating radar of high power, called Sting Ray. The Sting Ray beams are individually coded, so that each Bloodhound remains tuned to its own beam. Very extensive firing trials at Aberporth and Woomera have shown that the guidance system is first-class, and many targets have been "splashed" even by inert rounds.

Recently the Royal Swedish Air Board signed a contract with Bristol for an undisclosed number of complete Bloodhound systems on behalf of the Royal Swedish Air Force. The value of the contract may not be disclosed, but it may be taken as signifying the intention of Sweden—not a member of NATO and thus not scheduled to receive American equipment—to plan her land-based anti-aircraft missile system around this weapon. It is worth emphasizing that the flexibility of the Bloodhound system is such that it can be efficiently introduced into any national defence environment, and does not necessarily require integration into a specially conceived control and reporting organization.

Bristol are known to be working on improved versions of the missile, and the 18in BRJ.801 ramjet revealed last year by Bristol Aero-Engines should confer a very great in-



crease in performance. At present the system is probably radar-limited, and all portions of the system are probably being improved in parallel so that a new development stage can be finalized at a relatively early date.

Bloodhound Mk 1: length, 22ft 2in (with boosts, 25ft 3in); wing span, 9ft 3in; body diameter, 21in; firing weight, probably of the order of 2,500 lb (about 4,500 lb with boosts); flight speed, clearly at least Mach 2; range, "several score miles".

BOMARC

United States Air Force (Air Defense Command) and Royal Canadian Air Force; the missile is designated Intercepter Missile 99.

Type: Air-breathing, surface-to-air, long-range missile for area defence. Drawing: p. 890.

LARGEST anti-aircraft missile in the western world, Bomarc is now coming into operational service, and is proving that a big and costly weapon may well prove cheap in relation to the task accomplished. A full development history was contained in our 1957 review.

Bomarc's configuration was fixed several years ago, although the processes of refinement and "stretching" are continuing. The 33in-diameter fuselage has a length of 47ft 4in, and most of this is occupied by integral kerosine tanks for the cruise powerplants. In the nose is the extensive guidance system and the large warhead, and the permanently attached boost rocket is mounted in the tail. The high-mounted wing carries ailerons for twist-and-steer control, and Bomarc also has rear elevators and a vertical tail, the upper portion of which forms a rudder. In the IM-99A, the version currently in production, cruise propulsion is provided by twin pylon-mounted Marquardt RJ43-MA-3 ramjets, each with a diameter of 28in.

A typical Bomarc site will have 24 shelters or hangars, one for each missile. Inside each shelter the missile rests horizontally on its launcher, fully connected to all ground supplies and maintained in a state of instant readiness. Within two minutes of an alert being given, the hangar can be opened—either by opening out the left and right halves of the building (picture overleaf) or, in another type of shelter, by sliding back the roof—and the missile can be raised into the vertical position and launched. All this can be controlled by the nation-wide SAGE system, the firing being directed from hundreds of miles distant.

Initial rocket-boosted flight is substantially vertical, the Aerojet-General liquid rocket having a gimbal-mounted chamber to provide stability. After a few seconds, the twin ramjets light up, and during the climb the missile is rolled so that its top surface points in the general direction of the target. As cruising height is reached the elevators are given a negative angle of incidence, thus pulling the missile over on to its back; it then does a half roll, ending in straight and level flight pointing at the target. By this time the boost rocket cuts out. Initial guidance is by radio command from the SAGE system, the GPA-35 ground-control equipment effecting a continuous computation of the flight paths of the missile and target in order to ensure the most economical interception. When the Bomarc approaches within the general area of the target its own active-homing system locks-on to its quarry, and ground control is cut out of circuit. Thereafter the missile is capable of completing the interception independently. According to the U.S.A.F., one Bomarc collided with a drone head-on, a particularly commendable feat in view of the minimum radar return from such a target.

Prime contractor, and missile manufacturer, is the Pilotless Aircraft Division of the Boeing Airplane Company at Seattle, Wash. Chief contractor for guidance is the Air Arm Division of Westinghouse. Flight stabilization includes a gyro platform and other equipment by Lear. Ground support equipment is manufactured by A.C.F., A.M.F. and Food Machinery, and check-out equipment is contributed by Farnsworth Division of I.T. and T. Either a high-explosive or nuclear warhead can be carried, with proximity fuzing.

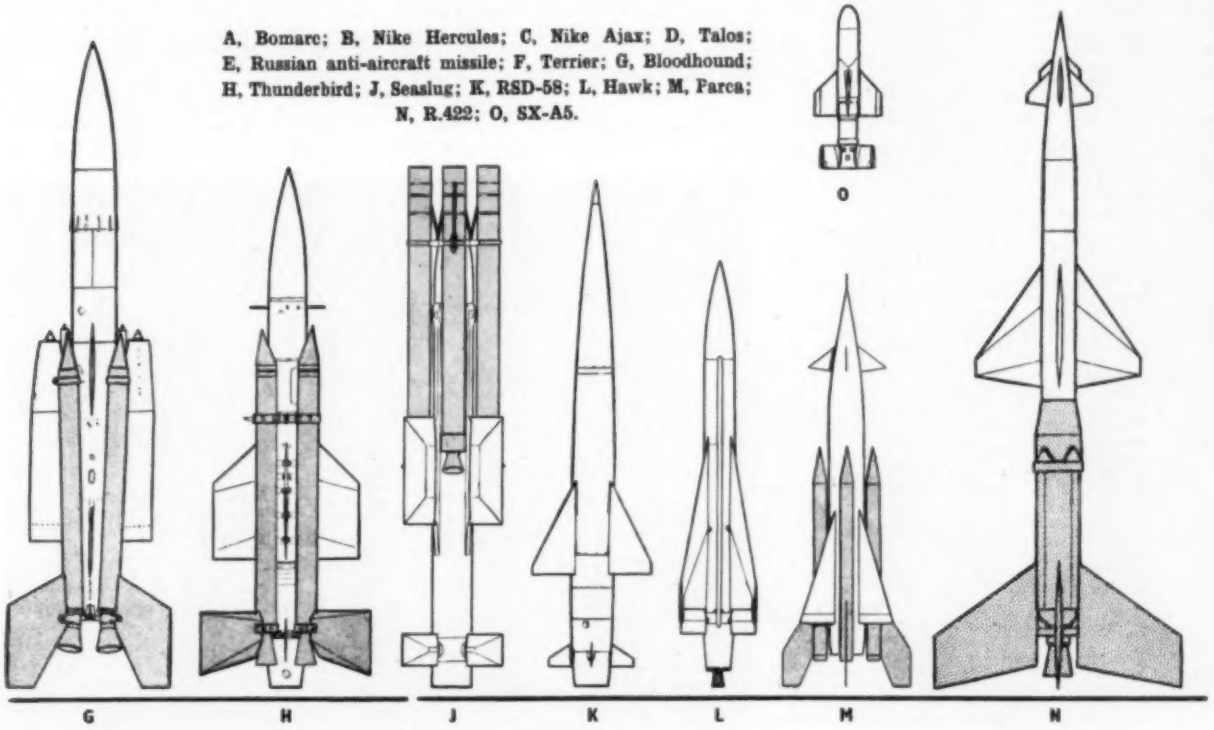
Test firings at Cape Canaveral have been undertaken progressively since September 1952. The principal Bomarc centre is now at Santa Rosa Island, in the Gulf of Mexico not far from Eglin A.F.B., where operational development, flight testing and indoctrination is taking place. Several rounds have been fired successfully at a variety of target drones, the launching being effected from a point 1,500 miles distant. One of the most remarkable interceptions took place on October 2, when an IM-99A (actually launched from Cape Canaveral) was fired under remote control from the SAGE centre at Kingston, N.Y. The target was a North American X-10, flying at Mach 1.6 at 48,000ft. The entire interception was controlled automatically. The missile carried no warhead and did not actually strike the X-10, but its instrumentation confirmed that it passed well within the lethal range, and would have destroyed the X-10 had a warhead been fitted. Total time from firing to interception 100 miles away was less than 5½ minutes.

Full production started in 1957 at the P.A.D. plant in Seattle, and the first production round was rolled off the line on December 30. The initial tooling and preliminary-financing contract for $7m was placed in July 1957, and a bulk inventory allocation of $139m followed in August. A further contract covering approximately one hundred IM-99As was placed last January; a production IM-99A is believed to cost in the neighbourhood of $350,000 exclusive of a nuclear warhead.

It is expected that up to 212 sites throughout the North American continent may eventually house missiles of the Bomarc family, and total production is unofficially estimated at up to 100,000 rounds (involving total expenditure of well over $10b). Boeing have proposed that there should be as many as 45, 80 or even 115 launchers at each site, constructional work alone involving $10m at each location. At present, however, Air Defense Command squadrons are being organized on a basis of 24 or 56 rounds apiece. The first four units will each occupy 300-acre sites adjacent to Dow A.F.B., Me.; McGuire A.F.B., N.J.; Otis A.F.B., Mass.; and Suffolk County A.F.B., N.Y. The allocation for constructional work at these four locations was $46 m. A comprehensive training school is maintained by Boeing at Harbor Island, Seattle, and courses of personnel from Air Training Command and Air Defense Command are at present being instructed. Ten additional bases are now under construction.

Shortly to come into production is the IM-99B Super-Bomarc. The most important advance made in this version is the incorporation of the more powerful RJ43-MA-7 ramjet. Performance figures for this engine are classified, but it is known that a recent test flight with one of these engines (driving a Lockheed X-7) resulted in a cruise speed of Mach 3.95 being

A, Bomarc; B, Nike Hercules; C, Nike Ajax; D, Talos; E, Russian anti-aircraft missile; F, Terrier; G, Bloodhound; H, Thunderbird; J, Seaslug; K, RSD-58; L, Hawk; M, Parca; N, R.422; O, SX-A5.



MISSILES 1958...

recorded at a height greater than 100,000ft. Another logical step is the incorporation in IM-99B of a solid boost rocket (presumably with provision for jet deflection); this unit, which will not be jettisoned at burn-out, is being produced by Thiokol. As far as is known, the fuel will remain kerosine, but additional tankage and the greater flight speed will result in a range approximately double that of the IM-99A. It is also possible that the airframe may be stiffened to enable interceptions to be made at low level—a critical shortcoming of the present missile. Flight-testing of IM-99B has already begun, and first deliveries of the improved missile are expected to equip the ninth Bomarc base late in 1960. The IM-99B is likely to go into service with the Royal Canadian Air Force in the same year.

Boeing are also known to be working on an even further improved missile stemming from the Bomarc family. However, the aerodynamic configuration will be entirely different, since a cruising speed of between Mach 5 and Mach 10 is envisaged (presumably outside the atmosphere). This vehicle is being developed in parallel with the company's Dyna-Soar orbital bomber, and is intended as an anti-ICBM weapon. Interception is intended to take place so high above the earth that fall-out can be ignored.

IM-99A Bomarc: overall length, approximately 49ft (body length, 47ft 4in); wing span, 18ft 2in; span of horizontal tail, 10ft 6in; body diameter, 33in; firing weight, approximately 15,000 lb; cruising speed, Mach 2.5; effective altitude, up to at least 80,000ft; maximum range, between 200 and 250 miles.

HAWK

United States Army (and probably Marine Corps); the missile is designated XM-3.

Type: Surface-to-air missile for use primarily against low-flying aircraft. Drawing: p. 891.

INTRODUCTION of the Hawk (Homing All the Way Killer) will close the last loophole in American defence against winged vehicles, for this missile can successfully intercept a supersonic target at tree-top level. It is one of the smallest surface-to-air missiles, and the overall system appears to be much simpler and more attractive than that of the Nike family. It is being developed in both fixed and mobile forms.

Prime contractor for the entire system is the Raytheon Manufacturing Co., at their new facility at Andover, Mass., and most of the airframe is manufactured by Northrop (wings are made by Temco). Propulsion is effected by a solid-propellant motor of high specific impulse made by Aerojet-General. The first portion of the charge burns with very high thrust as a booster, and the sustainer exhausts from a smaller, central nozzle. The case forms an integral part of the missile fuselage, and is made by Norris-Thermador as a deep-drawn cylinder in 4130 steel, the dimensions being 96in × 14in diameter and with a wall thickness variously 0.107 or 0.067in. Guidance is by radar semi-active homing. Raytheon have pioneered special radar techniques which can discern moving targets through intense ground clutter. Continuous-wave monopulse radar is used to guide Hawk; the ground set employs two dishes and can eliminate all return signals from stationary objects. The flight of the missile is controlled by surfaces carried behind the trailing edges of the four wings. Hawk can carry several types of warhead, some possibly nuclear, and has a proximity fuze.

Although the Army will use Hawk mainly in the fixed-base home-defence role, the complete weapon system has been made unusually mobile for operations in support of armies in the field. All portions of the system are readily air-transportable by helicopters or medium-sized aeroplanes. From Northrop's Nortronics Division the missiles are delivered in a shock-proof tactical container, and Nortronics also manufacture the pallets, loader and launcher. Food Machinery make the tracked transporter and launcher-loader, which carries three rounds at a time and slides them on to the three zero-length positions of the launcher. The radar rides on a soft-sprung vehicle by Fruehauf.

In fixed installations each army battalion would employ four batteries, each battery being capable of defending in two directions simultaneously. A battery would have twelve triple launchers, under dome covers which could be opened for firing. These fixed 40-acre installations are being developed by Raytheon and the first are being constructed near New York City and Washington/Baltimore. The importance of closing the low-altitude gap is indicated by the fiscal year 1959 obligation of $213m for this weapon system. The performance of the missile was publicly demonstrated at White Sands in July, when a Hawk collided head-on with a QF-80 drone flying at 500ft five miles away. The ground-guidance radar is stated to be capable of picking one aircraft from a close formation at a range of 22 miles.

XM-3 Hawk: length, 16ft; wing span, 50in; body diameter, 14in; firing weight, 1,285 lb; burn-out speed, approximately Mach 2.5; maximum slant range, about 22 miles.

MTG-CI-58

Italian Air Force.

Type: Beam-riding surface-to-air weapon system. Drawing: p. 891 (RSD-58).

SINCE 1956, Contraves Italiana have been licence-producing the Contraves-Oerlikon RSD-58 (*q.v.*) and RSC-57 surface-to-air missiles. The Italian-manufactured weapons are designated MTG-CI-58 and MTG-CI-57 respectively, the latter being at present in use as a training missile for the Italian Air Force. Extensive trials on the I.A.F. firing range in Sardinia during the past three years (initially with Swiss-built missiles) have enabled Contraves Italiana to offer the complete system in a fully developed form.

MTG-CI-58: identical with RSD-58 (*q.v.*).

NIKE AJAX

United States Army (throughout the U.S.A. and in Army locations in all parts of the world); the missile is designated SAM-A-7.

Type: Anti-aircraft missile system with radar command guidance, intended for operation from large fixed installations. Drawing: p. 890.

FULL details of this pioneer anti-aircraft system were given in our 1956 review, and additional facts were added in the 1957 issue. It incorporates a canard-type missile, with a tandem solid boost and an internal acid/kerosine container, guided by beam-riding and radar command from an extensive ground-guidance system. A computer continuously plots the target and missile, and at the appropriate moment injects a variation into the coding of the double-pulsed ground transmission to detonate the warheads. The latter are all high-explosive assemblies wrapped in "optimum fragments" (steel cubes measuring about 0.25in along each side), and the nose, centre and aft warheads weigh 12 lb, 179 lb and 122 lb respectively.

Prime contractor is Western Electric, who have shared the main guidance responsibility with Bell Telephone Laboratories. Airframe production has been handled by the Army Ordnance Missile Plant at Charlotte, N.C., operated by Douglas Aircraft. It has been said that by February of this year 16,000 rounds had been delivered, and contracts are now complete. A very extensive modification and field repair programme is now in hand to keep this vast stockpile of missiles serviceable and capable of giving sure performance at a moment's notice—a never-ending task, like the oft-quoted one of "painting the Forth Bridge." The programme is not made any easier by the fact that batteries normally contain 12 launchers (four to each of Alpha, Bravo and Charlie sections), where hundreds of missiles have already remained exposed for up to three years. Each section has underground storage. Sites are now being converted to fire Nike Hercules (*q.v.*), and the surplus Ajax will presumably be either fired, exported or dumped at sea when the cost of their repair and improvement becomes uneconomic. This is a problem which must sooner or later be faced by the sponsors of all missile systems.

SAM-N-7 Nike Ajax: overall length, 21ft (with booster, either 34ft 10in or 35ft 5in); body diameter, 12in; wing span, 63in; firing weight, 1,100 lb. (2,100 lb with booster); burn-out speed, about Mach 2.3; maximum slant range, about 25 miles.

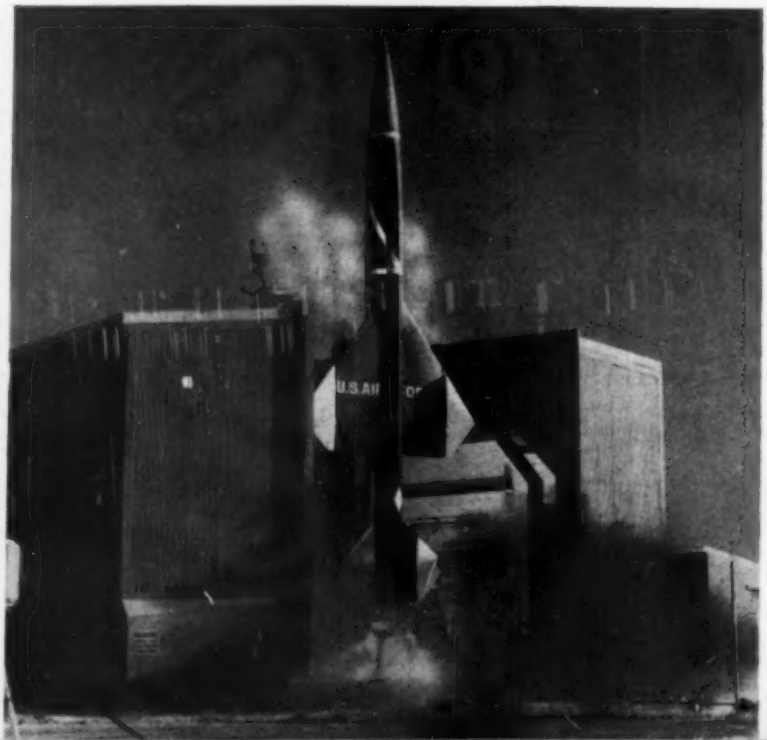
NIKE HERCULES

United States Army (in the U.S.A. and Formosa); the missile is designated SAM-A-25.

Type: Radar-guided missile for incorporation into the existing Nike system. Drawing: p. 890.

THIS journal's missile review issues of 1956 and 1957 have stressed the fact that the development of the Nike system was a task so huge and important to the security of the metropolitan United States that it had to be started at a very early date. In fact, it was commenced at a time when the overall technology of military electronics, missile design

Largest anti-aircraft weapon at present in use is the IM-99A Bomarc. One of these 47ft missiles is here depicted at the moment of leaving its launcher



DESTINATION APOGEE!

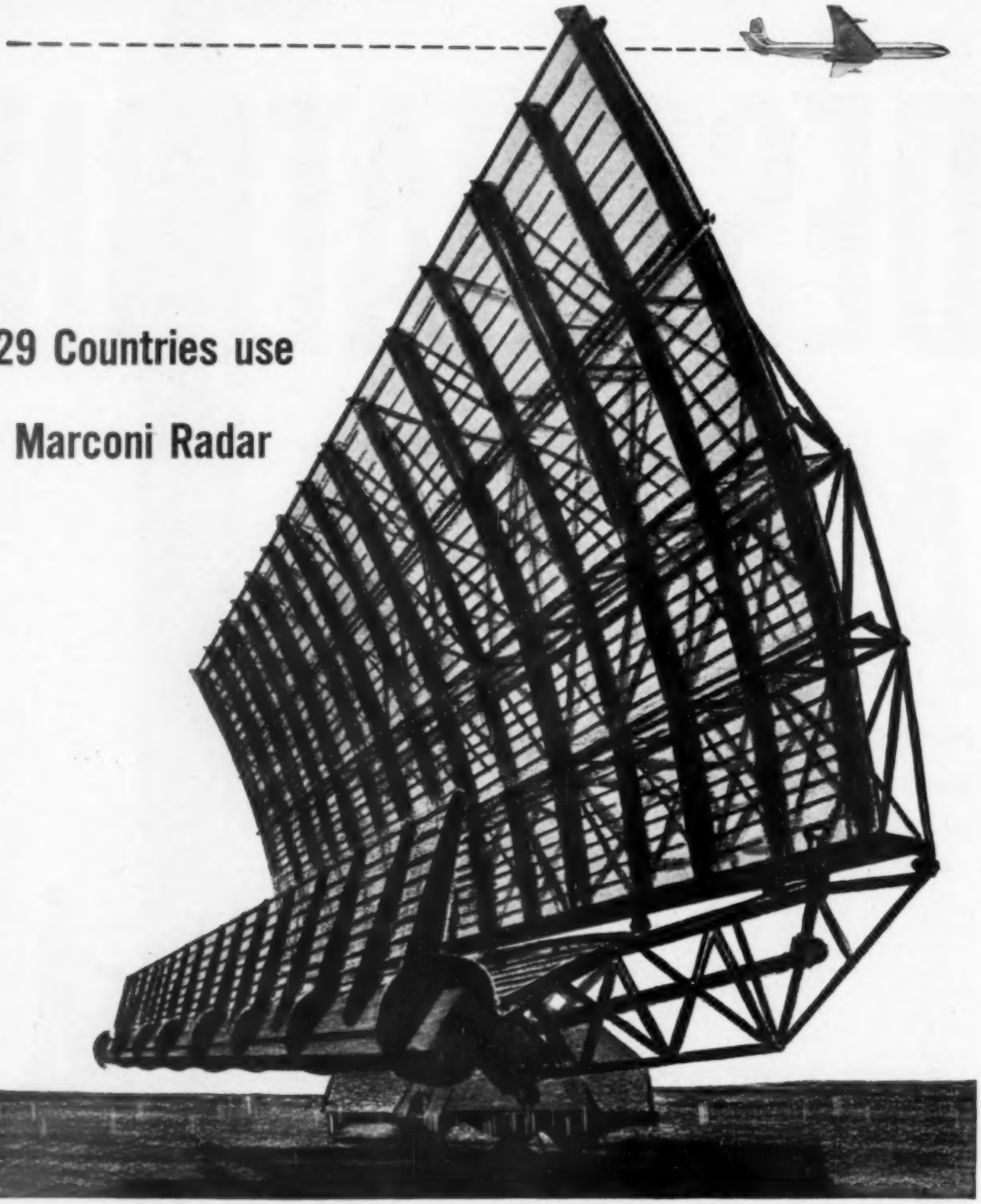
ARMSTRONG SIDDELEY ROCKET MOTOR SENDS BLACK KNIGHT TO 'SPUTNIK HEIGHT' ON FIRST TEST

ARMSTRONG SIDDELEY, who developed and produced the power unit for Black Knight, are proud to have been associated with the Saunders-Roe Company and the Royal Aircraft Establishment in the successful first launching of Britain's research rocket. Black Knight is designed to reach a maximum height — or Apogee, as the scientists call it — of several hundred miles above the earth's surface — ultimately to 1,500 miles.
Armstrong Siddeley is in the forefront of rocket research and development, and the company's new gas turbine and rocket research station is equipped to deal with any demands that may be made in the foreseeable future.

Bristol Siddeley

ENGINES LIMITED

Marconi in Radar



29 Countries use Marconi Radar

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and air defence generally was in its infancy. The resulting system is thus complex, immensely costly and far from being as efficient as it might be; but it is a *fait accompli*, too huge to be altered.

Nike Ajax as a missile is likewise complicated, expensive (the cost per round has, admittedly, been brought down by the enormous production) and not particularly efficient. Its successor, Nike Hercules, puts right everything that was wrong, except for the fact that it has to fit into the established Nike system and the American air-defence environment. It has been suggested that Hercules is "15 times as effective" as Ajax, and, while this assertion means little, it does give an indication of the vast difference in lethality between the two weapons.

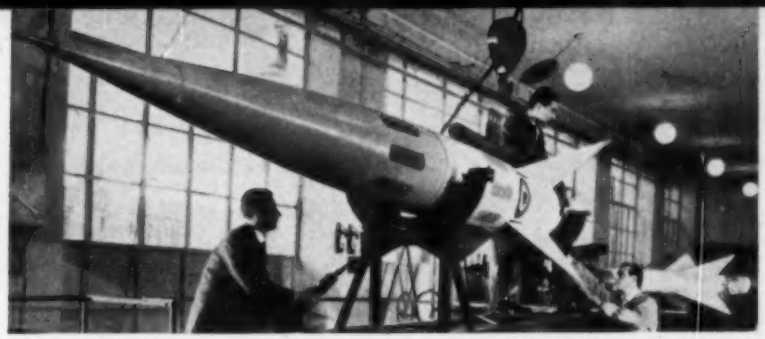
Like Ajax, Hercules is the prime responsibility of Western Electric. Its manufacture has succeeded that of Ajax at the Charlotte Ordnance Missile Plant operated for the Army by Douglas Aircraft, who handle further Nike work at Burlington, Greensboro and Winston-Salem (like Charlotte, all in North Carolina). The vehicle is very much larger than Ajax. The canard configuration of the earlier missile has given way to a cruciform of acute delta wings with trailing-edge control surfaces, resulting in a much higher order of manœuvrability, especially at high altitudes.

Boost propulsion is provided by a tandem package made by Radford Arsenal and Borg-Warner, incorporating four Ajax-size boost motors by the Hercules Power Co.; a Thiokol self-destroying booster is under evaluation. The sustainer is one of the new series of high-impulse solid motors by Thiokol, made at the Army Ordnance works at Marshall, Tex., operated as Thiokol's Longhorn division. The solid charge is situated around the missile c.g. and is connected to the nozzle through a long blast tube. Airborne power services are energized by an accessory power unit by AiResearch.

Guidance has to remain radar command, involving the three basic radars, ground computer and auto plotting boards which are to be found at all Nike sites. Radar power is being substantially increased to match the greater range of the new missile. It is hoped to introduce terminal homing ability, although a non-homing round fired publicly at White Sands in July was detonated less than 50ft from a 650 m.p.h. target at a range of 50 miles. Hercules carries a large and very effective warhead, and a nuclear-tipped version is also just coming into production. General Electric fuzing is employed for the latter.

Production at Charlotte is now running at a high rate. Concurrently, immense sums are being spent on converting existing Nike sites to handle and fire both the present stocks of Ajax and the Hercules now being delivered. Launching and major handling units have to be replaced, and this work is being done by Consolidated Western Steel, assisted by Wayne Pumps, A.M.F. and Douglas. Shipping and storage containers are made by Food Machinery and transporters by Douglas and Fruehauf. Western Electric are receiving large contracts for the improved guidance units, typical sums being $129.6m in March (plus $3.4m for "preparation of ordnance documentation"), $47.97m in May and $66m in June of this year. Site conversion is being done by local building contractors, whose contracts are running at about $1.5m each.

Like Ajax, Hercules is installed in units comprising four batteries, occupying 150 acres of Army-owned land (plus a further 350 acres in "easements"). By June of this year all the batteries around New York City, Washington D.C. and Chicago had been converted to the new missile, and a complete Hercules battalion went to Formosa in October. In the latter month eight distributed units were operational, and by the middle of next year almost all the Army's 73 anti-aircraft missile battalions (only 13 are left with guns) will be Hercules-equipped. The Army missile has had a hard fight to retain its place in competition with the Air Force IM-99, but Continental Air Defense Command has agreed to the operation of both indefinitely.



Anti-aircraft missiles of Contraves-Oerlikon type are manufactured by Contraves Italiana as the MTG-CI-58 (p. 892). These missiles are here seen in production in the Rome plant

SAM-A-25 Nike Hercules: overall length, about 26ft 9in (41ft 6in with booster); body diameter, 28in; wing span, 105in; firing weight, approximately 5,000 lb (10,000 lb with booster); burn-out speed, Mach 3.35; effective ceiling, over 90,000ft; maximum slant range, at least 70 miles.

NIKE ZEUS

United States Army.

Type: anti-ICBM missile for integration into the existing Nike/SAGE system.

INTENSIVE research into the problems of intercepting the warhead of a ballistic missile—an ICBM in particular—started some three years ago, and appraisals of the work done in the past were contained in our 1956 and 1957 missile review issues under the heading of "Antis." The picture has now been rationalized, and the missile portion of the system is to be the Army's Nike Zeus. It is to be deployed in 1964.

First link in the chain must be a surveillance radar of immense power and discrimination. To be produced by R.C.A., this is likely to be an improved version of the existing FPS-17 sets which have long been used for tracking Russian ballistic missiles from sites in Turkey and Iran. As an acquisition radar it is almost certain to employ twin pencil beams, one at an elevation a fraction of a degree higher than the other, and both beams will be rapidly swept in azimuth across a horizontal arc. The lower beam will be the first to pick up a return from the approaching missile, and the latter's trajectory can then be calculated from its passage across the two beams in succession. Three of these radars are to be set up in the Arctic under a $160m appropriation in the current fiscal year; each will sweep 45 deg in azimuth, so the three together will blanket the entire Soviet land-mass.

Data from these giant installations will be fed to the next stage, which will consist of parabolic-scanner tracking radars, by Sperry. Each of these will be essentially similar to that at Millstone Hill, Mass., currently used for tracking missiles fired from Cape Canaveral and elsewhere. The Millstone radar has an 84ft dish, producing a 2-deg beam with a peak power of about one megawatt. The tracking radar will be capable of locking-on and determining the trajectory of the oncoming vehicle with sufficient accuracy for its target to be alerted and an "anti" to be fired with fair certainty of effecting an interception.

The anti itself is the Zeus missile, which represents the third stage in the Nike family. A mighty weapon system, with a big missile, the programme is already in a stage of development in which any major change would cause severe disruption of hardware. Prime contractor is, as before, Western Electric, plus Bell Telephone Laboratories and Douglas Aircraft for programme development and airframe development. The vehicle configuration is generally similar to that of Hercules, although on a larger scale, and Thiokol, the boost contractor, recently static-tested a 450,000 lb-thrust solid-propellant booster which seems to suit the missile exactly. The sustainer and vectoring motor will be by the Grand Central Rocket Co. Douglas will make the airframe, with tremendous scientific backing in such fields as hypersonic aerodynamics (or super-aerodynamics), heat-resistant structures and other related problem-areas, by ten powerful agencies.

At the firing site there will be two main radars, both by Western Electric, for tracking the incoming warhead and the missile. Linked by a computer, these sets will guide the Zeus on its journey of some hundred miles into the interception region, where the missile and incoming warhead meet. The Zeus will have its own seeker, by Ryan, inside a ceramic radome (Coors Porcelain Co.), as well as a doppler (Ryan) to pick out the speeding warhead among a possible host of slower decoys. The Zeus warhead will, of course, be nuclear.

Name of the Army weapon system is Project Plato. The competing Air Force system was Wizard, but the latter has been shelved, apart from special research into data-processing and detection radars which are more sophisticated than those of the Plato system. At present no decision has been taken to put Zeus into production—at present its kill-probability is placed at only 25 per cent—but the research and development phase is being hastened along on a broad front. An immense army is at work on it (42 contractors have already been named), and fiscal year 1959 allocates $130m to be "obligated for maximum effort on the development of Zeus as a defense system against ballistic missiles." Incidentally, the system could well profit from British developments in the sphere of long-range detection.

Nike Zeus: overall length, possibly 60ft with booster; firing weight, at least 20,000 lb with booster; burn-out speed, probably more than Mach 5; interception range, about 100 miles.

PARCA

French Army.

Type: Command-guided surface-to-air weapon system. Drawing: p. 891.

SINCE our 1957 review, in which the history and characteristics of this missile system were outlined, no further information on its progress has become available. A canard, guided by a Nike-type radar command system, Parca is launched at any angle between 30 and 90 deg under the thrust of four wrap-round boost motors, thereafter climbing on the S.E.P.R. solid sustainer. A considerable number of rounds have been fired at Colomb-Bechar and Parca is known to be in limited service as a training weapon with the French Army.

Parca: length, 16ft 5in (approximately 18ft with boosts); wing span, 63in; firing weight, 2,200 lb; burn-out speed, March 1.5; effective ceiling, 65,600ft.

R.422

French; no information is available on whether or not this missile has been adopted for use.

Type: Radar-guided surface-to-air missile. Drawing: p. 891.

ONE of the first surface-to-air missiles to be developed in France, the R.422 is intended for the interception of bombers flying at between 10,000 and 66,000ft at between Mach 0.5 and 2. More than one type of R.422 has been fired, the first version having boost propulsion by a tandem package of four solid-propellant motors and the latter version having a large single boost. The missile is a canard and guidance is effected by a Nike-type system, with radars for tracking the target and missile (which carries a transponder) so that, with the aid of a computer, the courses of the target and missile can be continuously compared and the weapon steered by radio command. When the missile is in the neighbourhood of the target, terminal guidance of the semi-active homing variety is brought into action, and the warhead is finally detonated by the proximity fuze. The homing receiver incorporates four aerials disposed within a radome on the nose of the missile.

R.422 is fired from a rotatable launcher at an elevation which can be varied between 30 and 90 deg. Prime contractor is Soc. Matra, chief sub-contractors being Cie. Francaise Thomson-Houston (radars), SFENA (radio command and terminal homing), S.E.A. (computer) and S.E.P.R. (boost and sustainer motors).

R.422: no quantitative information available.

RSD-58

Swiss Armed Forces and Japanese Defense Agency (also see the MTG missiles, manufactured in Italy).

Type: Surface-to-air weapon system developed as a private venture. Drawing: p. 891.

DURING the past decade, Contraves A.G. together with the Armament Division of the Oerlikon Machine Tool Works (Bührle and Company), both of Zurich, have been assiduously developing this weapon system as a private venture, and it is now offered for sale "over the counter." Extensive trial firings were carried out in Switzerland and France in 1950 and 1951, and early in 1952 the U.S. Air Force evaluated 25 of the Type 51 missiles at Holloman A.F.B.

The standard anti-aircraft missile this year is the RSD-58. The finely streamlined body is made from wrapped tubing and sheet with Araldite bonding, and the delta wings are of sandwich construction. Propulsion is provided by a 2,200 lb-thrust nitric acid/kerosine sustainer (no booster is used) and the missile is controlled by a cruciform of tail fins (and, during the launching, by deflection of the motor chamber).

Missiles are fired at any elevation from 10 deg to 90 deg from a twin launcher, which may be mounted on a mobile chassis. After gathering in a wide radar beam, the missile is centred in a fine guiding beam and rides this until the proximity fuze detonates the 88-lb warhead. A complete tactical battery comprises a command post, radar tracker, beam transmitter, six twin launchers and the necessary power-supply units. The sustained battery rate of fire can reach twelve rounds per minute, i.e. two rounds per minute for each twin launcher.

For training purposes, the RSC-57 is almost identical to the operational missile, except for the fact that the warhead is replaced by a parachute recovery system, and the quantity of propellants is reduced so that the range and burn-out speed are roughly one-third as great as in the RSD-58. The RSC-57 is in service as a training missile with the Italian Air Force and has also been delivered to the Japanese Defense Agency, together with a complete school battery for test, evaluation and training purposes.

RSD-58: length, 19ft 8in; wing span, 53in; body diameter, 15.7in; firing weight, 882 lb; burn-out speed, Mach 2.4; maximum controllable altitude, 65,600 ft; maximum controllable slant range, 33,000 yd (18.6 miles).

RUSSIAN A.A. MISSILE

Believed to be in service with Soviet Army and Air Force; the weapon is unofficially reported to be designated M-2.

Type: Radar-guided, surface-to-air missile for operation from fixed and mobile bases. Drawing: p. 890.

NO further information has become available since this missile was first seen in the Red Square parade in November 1957. All that could reasonably be deduced was published in our last missile review. Of "British" configuration, with cruciforms of wings and rear-mounted control fins, this missile is launched by a tandem boost motor and appears to have beam-rider or command guidance. The nose is not a radome, but it carries four blade arials.

Russian A.A.: length, approximately 21ft (30ft with booster); body diameter, about 18in; wing span, approximately 69in; firing weight, about 1,500 lb (about 2,500 lb with booster); burn-out speed, probably about Mach 2; maximum slant range, probably about 20 miles.

SEASLUG

Royal Navy.

Type: Radar-guided surface-to-air weapon for use from surface vessels. Drawing: p. 891.

THE first relatively complete account of the development of the Seaslug weapon system was published in our issue of November 21 of this year. Its development has been the responsibility of three chief contractors: Armstrong Whitworth Aircraft for the airframe, and for several other portions of the weapon system, as well as flight testing; G.E.C. for the guidance system (which incorporates packaged units housed in pressurized and air-conditioned boxes); and Sperry for the control system. The latter includes a control package, surrounding the sustainer-motor tube at the rear of the missile, which moves the four control fins.

Like the wings, these fins are of rectangular plan-form, and the fin and wing cruciforms are indexed in line. In order to eliminate the need for boost-motor stabilizing fins (and thus reduce the bulk of the boosted round to about one-quarter of that occupied by comparable land-based missiles) it was decided to mount the boost motors on the fore-body of the missile. So important is the need to minimize bulk that the nose of each of the four large boosts is completely unfaired, the front of each motor being terminated by a flat disc. Hidden by the four boosts is the ogival nose, in which presumably is housed part of the guidance system. A high-impulse solid sustainer is used, replacing an acid/methanol motor employed on the test vehicles.

Seaslug will form the primary anti-aircraft armament of the four "County-class" fleet-escort super destroyers now under construction. Each of these ships will carry a triple Seaslug launcher on the quarterdeck, fed from large internal magazines. Rounds will be stored in the boosted and fully operational condition on magazine trollies mounted on a transverse rail system. It will be possible to select individual rounds—chosen according to serviceability, type of warhead, or other variables—from a central control room. The missile chosen will then be moved sideways, lifted by a hoist off its trolley (which will return to its place) and into a longitudinal conveyor system.

The latter will take the form of a four-rail system along which the Seaslugs will be moved hydraulically by a lug engaging with a socket on one of the boost motors. At one point a transverser will permit the missiles to pass from one conveyor to the next, or into a check-out and test room. At the output end (i.e., the stern end, in the County ships) a tilting loading cradle will rotate the Seaslug into a position from which it can be slid straight up into the launcher by means of hydraulic rammers. A triple launcher will, of course, be served by three parallel conveyor systems.

Many Seaslugs have now been fired, both from shore bases and from the Royal Navy guided-weapon trials ship *Girdle Ness*. A variety of targets have been successfully engaged, and, on more than one occasion, the firing of a brace of Seaslugs has resulted in the first round hitting the target and the second missile striking the largest remaining piece of wreckage. Last week *Girdle Ness* returned to the United Kingdom after an extensive series of trials in the Mediterranean. Over 100 Seaslugs were fired, and the weapon was described as being "the best the Navy has ever had."

Seaslug: overall length, about 20ft (the boosts appear to terminate in line with the nose, and so do not affect this dimension); wing and fin span, both about 60in; body diameter, about 19in; firing weight, probably about 2,000 lb (about 4,000 lb with boosts); burn-out speed, probably over Mach 2; maximum slant range, probably more than 20 miles.

SX-A5 DEVELOPMENT

Royal Navy.

Type: Small guided weapon for surface ships.

SECURITY prevents the publication of any details of this new weapon system, which is being developed for the Royal Navy by Short Brothers and Harland, Ltd., at Queen's Island, Belfast. It has, however, been officially stated that it is intended to replace light anti-aircraft guns at present used in all classes of surface ship, implying production of thousands of rounds. In fact, the Parliamentary Secretary to the M.o.S. has written "if it is the success we are expecting, it should lead to . . . production orders extending over a number of years."

It is likely to be descended from the SX-A5, which was described and illustrated in our 1957 review. Aerodynamically following the same configuration as Malkara (p. 886), the SX-A5 is steered by a cruciform of moving wings and is propelled by a two-stage solid-propellant motor. Guidance is likely to be of the radio-command type and tracking flares have certainly been fitted to the SX-A5s so far seen. A drawing of the SX-A5 appears on p. 891.

SX-A5 Development: all data restricted.

SX-A5: length, 77.2in; span of wings and fins, 31in (the fins are indexed at 45 deg to the wings); weight and performance data restricted.

TALOS

United States Navy; for development and evaluation, the United States Army.

Type: Fully automatic anti-aircraft system for use from large surface vessels, with development continuing upon a land-based version. Drawing: p. 890.

SINCE our 1957 review the SAM-N-6 Talos, the most expensive and complicated naval weapon system in the world (excluding Polaris) has gone into operational service aboard the cruiser *Galveston*. The vehicle itself is unique among operational missiles in having an integral ramjet body. Boosted from a rail launcher by a large tandem solid motor, the missile ramjet lights up at supersonic speed as soon as the boost falls away and allows the airflow to start. At present the fuel used is kerosine.

As it descended from the Bumblebee project at Johns Hopkins University (see our 1957 review for history) Talos has fixed fins and a moving cruciform of wings. Terrier, originally a hastily conceived stop-gap for Talos, is a much smaller missile. Most Talos at present have a high-explosive warhead. These rounds are equipped for mid-course guidance by riding a pencil beam into the target area, whereupon the terminal semi-active homing system takes over, the target being illuminated by the powerful SPG-49 shipborne radar made by Sperry's Surface Armament Division. There are four semi-flush and spike aerials around the double-shock intake in the nose of the missile. The large warhead occupies one of the 6in-deep annular bays around the 18in ramjet, and is detonated by a Melpar proximity fuze.

Nuclear-warhead Talos are now also in full production and in service, a great deal of pioneer work being accomplished to make this possible. Owing to its much greater lethal radius the nuclear-Talos guidance system is devoid of the semi-active terminal phase.

Manufacture of the missile is handled at Mishawaka, Ind., by the Missile Section of Bendix Products Division, the ramjet body being constructed by McDonnell Aircraft. Joint prime contractor with Bendix is R.C.A., who have handled much of the guidance system, including the outstandingly accurate FPS-16 tracking radar. Ship systems are managed by Vitro Corporation, and include extensive magazines, auto selectors (by G.E.) for choosing the correct type of missile and feeding it to the twin-launcher (Northern Ordnance), Sperry SPW-2 surveillance radar, Mk 2 target-tracking weapon detectors and Mk 3 computers. Recently the chief of the Navy Bureau of Ordnance, Rear-Admiral F. S. Withington, complained that radar remained the weakest link in the Talos system. Aerial weight, he said, was limited to about 10 to 16 short tons, and the range to below 200 miles. Of this range he said "I'll be pleasantly surprised if we get it."

For more than two years the Army have been working on a land-based version of the system, and at one time the Air Force also wanted Talos (to protect S.A.C. airfields). Notwithstanding the excellence of the missile itself, the Talos LBS (land-based system) is likely to founder. R.C.A. and A.M.F. have worked hard to evolve a compatible arrangement of radars, magazines, launchers and computation and check-out gear, but, according to one authority, "they came up with automatic precision equipment that would do justice to a modern oil refinery." Sophisticated and automatic shipboard systems do not seem at home in jungle and desert. Nevertheless the LBS did achieve a superb strike on a Mach 2 Kingfisher target last August.

Development of LBS is continuing, and the Navy are also evolving a super-Talos, which will have fully modular electronics, improved guidance, a larger boost of increased specific impulse and greater internal tankage. The range is expected to start at 80 miles and work up to 100. The Bureau of Ordnance is continuing studies against land and sea targets, and an advanced project exists for an anti-missile Talos, possibly with twin engines and flying at over Mach 5.

SAM-N-6 Talos: overall length, approximately 21ft (31ft with booster); body diameter, 30in (containing an 18in integral ramjet); wing span, 102in; firing weight, approximately 3,300 lb (about 6 500 lb with booster); cruise speed, about Mach 2.7; maximum slant range, currently about 50 miles.

TARTAR

United States Navy.

Type: Beam-riding missile system for installation aboard relatively small surface vessels.

DURING the past three years the technology of solid propellants has permitted the attainment of much higher specific impulse. The resulting extension in missile range and performance which such motors can facilitate has assisted the U.S. Navy to produce Tartar, a miniaturized Terrier which can do all that the larger and earlier missile can do.

Tartar is reported to be a single-stage missile, weighing a bare 950 lb at firing. Guidance is effected by a beam-riding system, for which Sperry received a $27.5m BuOrd contract in July (in respect of ship's radar) and Ford Instrument a $14m contract at the same time (for the Mk 118 computer). These units are lighter and smaller than the shipborne portions of the Terrier system. Maximum slant range is likely to be about 15 miles, so that one Tartar frigate or destroyer could protect a wide area. The missile is scheduled to be in service by 1960, and pilot-line production by Convair at Pomona, Cal., is stated to have caught up after an earlier "slippage." Output seems, in fact, to be restricted by the Navy's inability to finance the ship-conversion programmes as fast as it would like to.

Tartar: dimensions somewhat less than those of Terrier (without booster); firing weight, probably about 950 lb; burn-out speed, probably at least Mach 3; maximum slant range, at least 15 miles.

TERRIER

United States Navy and Marine Corps (soon to be issued to the navy of Italy and possibly to other NATO nations); the missile is designated SAM-N-7.

Type: Beam-riding missile for firing from larger surface ships. Drawing: p. 890.

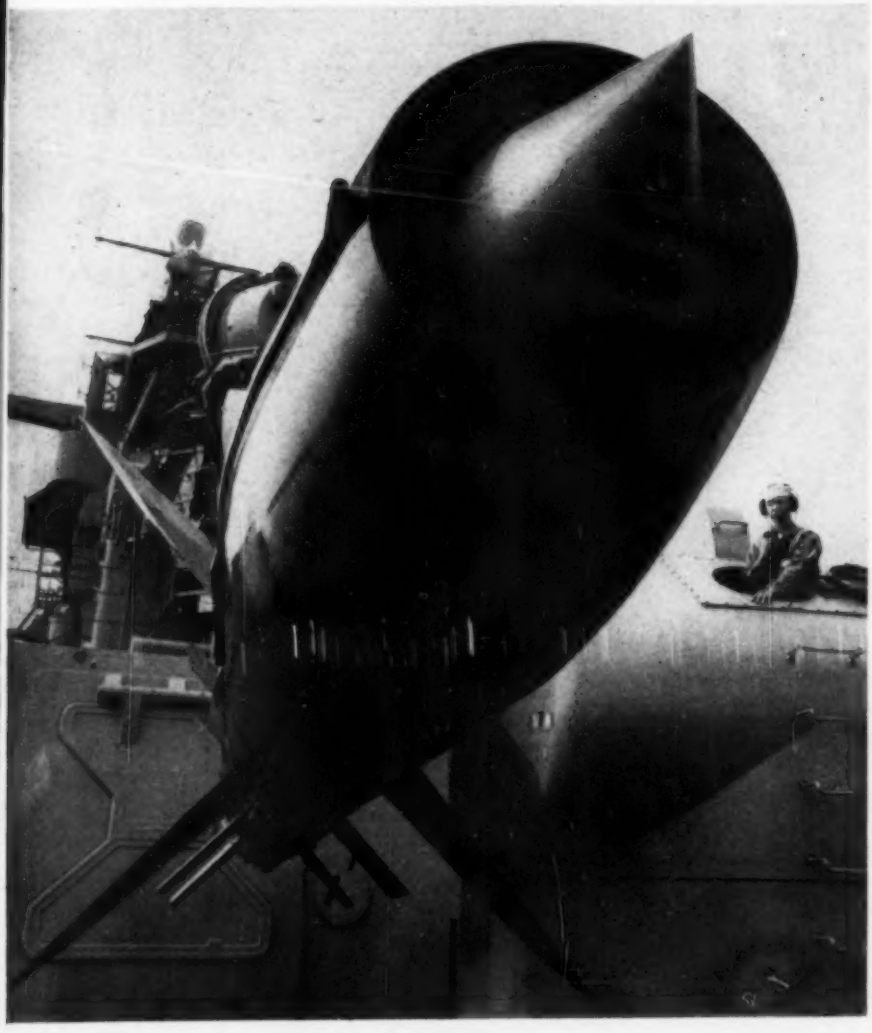
HISTORY and details of this familiar weapon system were contained in our 1957 review issue. The missile itself, made at Pomona, Cal., in a new plant operated for the Navy Bureau of Ordnance by Convair, is one of the smallest surface-to-air missiles. Powered by a tandem solid booster, and incorporating an internal solid sustainer, it has a fixed cruciform of rear fins and is controlled by the cruciform of pivoting wings. It carries a high-explosive warhead and has beam-riding guidance by Sperry and Reeves (ship's radar), Ford Instrument division of Sperry-Rand and Western Electric. Automatic handling by Baker-Raulang feeds the Northern Ordnance twin launcher.

Several thousand rounds have been delivered on schedule, and production of Terrier is tailing off; cost per round seems to be running at about $40,000. Several ships are armed with Terrier, the total programme involving 22 ships due for commissioning by the end of 1961. The Marine Corps has a land-based version, the components of which are being "integrated" by Vitro and Universal Match.

Now in production is the Terrier II, in which a sustainer of higher specific impulse and a slightly larger airframe result in much increased range (reported to be 20 miles) and permit the incorporation of terminal homing guidance. The latter is very valuable, in that it relieves the ship of the necessity of carrying quite such bulky and weighty radar as that needed by Terrier I, and thus Terrier II could be installed on ships of rather smaller size.

Terrier I: length, 14ft 9in (26ft 5in with booster); body diameter, 13in; wing span, 47in; firing weight, 1,100 lb (about 2,300 lb with booster); burn-out speed, about Mach 2.5; maximum slant range, 10 miles.

The nuclear Talos differs from h.e. rounds in having no semi-active homing system. It can be distinguished by the fact that no aerials and sensing tubes mar the circumference of the intake



THUNDERBIRD

British Army and (evaluation) Royal Air Force; the weapon system bears the code name of Red Shoes.

Type: Semi-active homing surface-to-air missile for mobile or fixed units. Drawing: p. 891.

DESIGNED and developed by The English Electric group of companies, Thunderbird is now one of the most refined anti-aircraft missile systems in the world. Many hundreds of test vehicles have been fired both from the R.A.E. range at Aberporth and from the W.R.E. at Woomera. Airborne targets have been engaged successfully many times during the past three years.

Like the majority of British guided weapons of its generation, Thunderbird Mk 1 has a cruciform of fixed wings and a rear cruciform of control fins. The light-alloy body has an ogival nose of dielectric material and a boat-type tail. Thunderbird test vehicles were fitted with liquid-propellant sustainers, but the production missile has a solid sustainer, which undoubtedly has a high specific impulse and probably gives a range at least as good as that originally obtained with the liquid motor. Four wrap-around boost motors are used to provide the acceleration needed for zero-length launching at a high angle of elevation.

Rounds are delivered from the plant at Stevenage, Herts, in sprung cradles in rigid metal containers, in which they may be stored for years in all climates. After being unpacked, the missile bodies are mounted on railed trollies in a field assembly and test point (F.A.T.P.), and the airborne radar and warhead are attached. The guidance is energized by a powerful "lamp set" on the ground, usually the B.T.H. Sting Ray, which illuminates the target with a pencil radar beam. Reflections from the target are picked up by the receiver dish in the nose of the missile and converted into signals which govern the hydraulic circuits of the controls. The radar receiver is checked on a go/no-go basis in the F.A.T.P. by a simulated target injector.

Wings and control fins clip on in a few minutes, and the boost motors are the last major items to be added. The round is then transferred to its launcher-loading trolley and towed to the launcher. The loading trolley is so designed as to permit the missile to slide off on rails and directly on to the launching base, which can be in a fixed emplacement or mounted on road wheels. Thunderbird can operate in a variety of electronic environments, but in the United Kingdom targets are automatically detected, tracked and assigned to intercepters or missiles. The Thunderbird is probably locked on before it leaves the launcher.

In view of the fact that it is to be standard equipment with Army formations throughout the world the entire missile system has been made exceptionally simple to service. Maintenance by replacement is the principle adopted, and minor and major units can be unplugged and replaced in a matter of moments; even the airframe can be taken apart without special tools in a very short time. Apart from the elimination of fairings at the wing roots the production round strongly resembles the early Red Shoes test vehicles.

It is worth noting that the increasing specific impulse of solid sustainers is, in American weapons at least, outstripping the ability of ground radar to provide effective guidance over the whole range available, and modified versions of the Thunderbird system may be in prospect. A fully-active version, however, seems unlikely. Acceptance trials are believed to be taking place now, and delivery to user batteries should soon start. It is not known what branch of the R.A.F. will employ the weapon but an order was placed by the M.o.S. on behalf of that service 15 months ago.

Thunderbird Mk 1: overall length (with or without boosts), 21ft; wing span, 44in; body diameter, 21in; firing weight, probably about 2,200 lb (more than 4,000 lb with boosts); burn-out speed, probably over Mach 2; maximum slant range, probably well over 20 miles.

MISSILES 1958...

AIR TO AIR

AA.20

French Air Force and Navy (possibly to be adopted by other NATO countries).

Type: Command-guided air-to-air missile. Drawing: p. 896.

DEVELOPED and manufactured by Nord Aviation S.N.C.A. as the Type 5103, this neat missile is exceptionally simple; thousands have been manufactured and many hundreds fired. Like the Nord S.S.11 anti-tank missile, the 5103 has a cruciform of fixed wings, canted slightly to impart spin, and no aerodynamic controls. Steering is effected by deflecting the jet from the solid sustainer (the first portion of which burns at high thrust as a booster), the guidance being radio command from a small cockpit joystick. Tracking is visual line-of-sight, the warhead finally being detonated by a proximity fuze.

More advanced versions of the 5103 are in advanced development. In addition, a SHAPE requirement exists for an air-to-surface weapon suitable for firing from the Fiat G.91, and the 5103 seems to fulfil this need admirably. Already the missile has been fired from the G.91 during development trials (and from almost all modern French fighters).

Nord AA.20: length, 8ft 2.4in; body diameter, 10.5in; wing span, 36in; firing weight, 298 lb; maximum flight speed, Mach 1.7; maximum effective range, about 2.5 miles.

CONTRAVES C.7

Italian Air Force.

Type: IR-homing air-to-air weapon of simple character.

CONTRAVES ITALIANA, the company developing this missile, ask us to exclude it from this review issue. Brief details were published in our 1957 missile issue.

DIAMONDBACK

United States Navy.

Type: Air-to-air missile.

AS stated in our 1957 review, this is reported to be the name of a development of Sidewinder (*q.v.*). Further information on this missile is expected to become available next year.

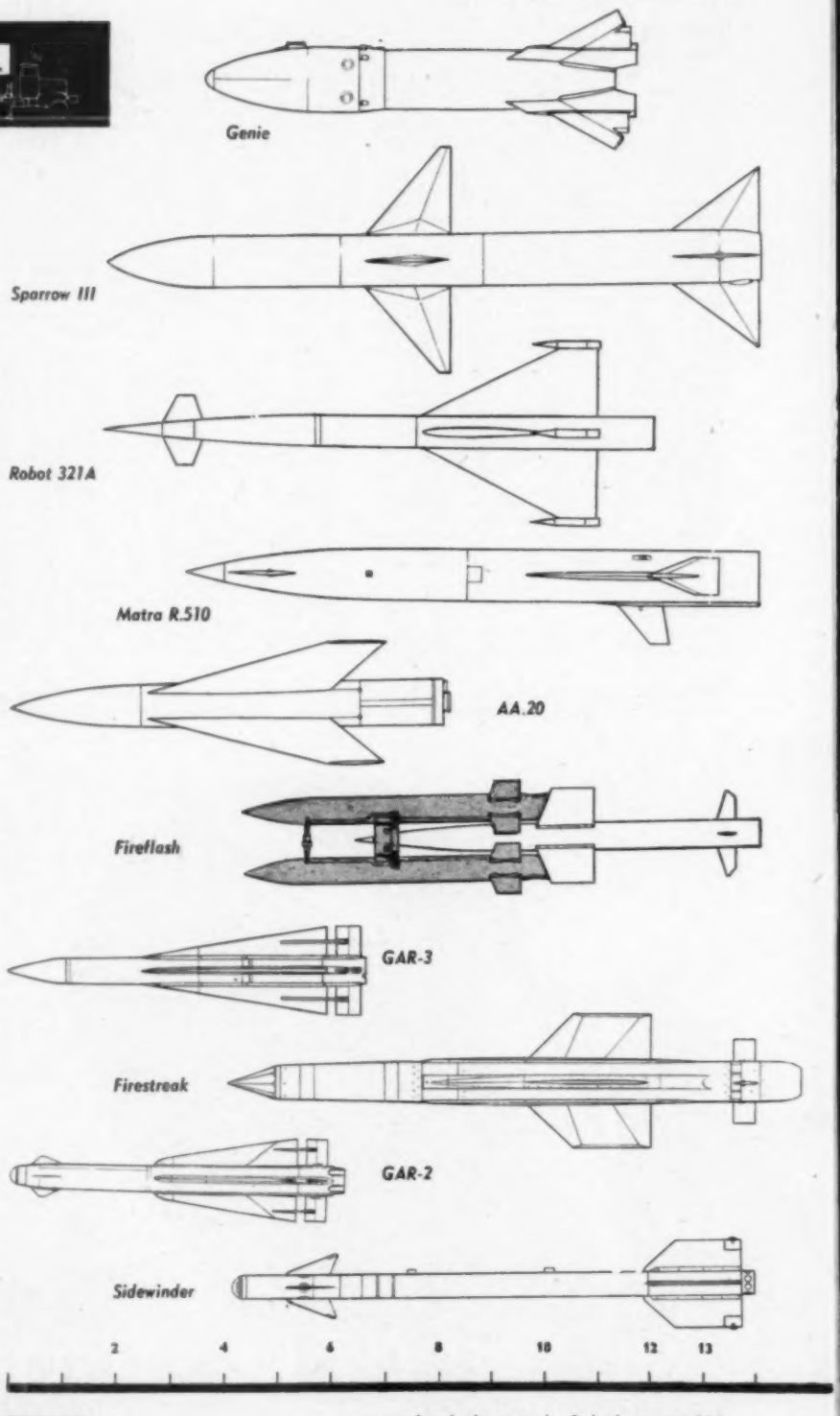
EAGLE

United States Navy.

Type: Large, long-range air-to-air missile for launching from "stand-off" aircraft.

FOR at least a year the U.S. Navy have been attracted by the concept of defending a fleet by an aircraft/missile combination in which the burden of effecting the interception is transferred almost wholly to the unmanned portion. Eagle is to be the name of the missile concerned, and it is intended to have range and lethality so outstanding that it can be launched from a stand-off aircraft—such as a Grumman A2F—the sole task of which will be to lift the Eagle to a useful altitude and then conduct a standing patrol, without attempting to close with a target.

Should an enemy bomber be detected, the Eagle-carrier would fly towards it—with all speed—and at the earliest possible moment release its weapon. The Eagle would then fly a distance of at least 50 miles (and possibly as much as 100), using its own active-homing radar to complete the interception. Its warhead will be nuclear. It has been reported that most of the weapon system is being assigned to Northrop, except for the guidance and guidance check-out gear, which will be handled by Westinghouse. At present Eagle is politically involved in a battle with the GAR-9 of the U.S.A.F. and with the ever-present budget trouble.



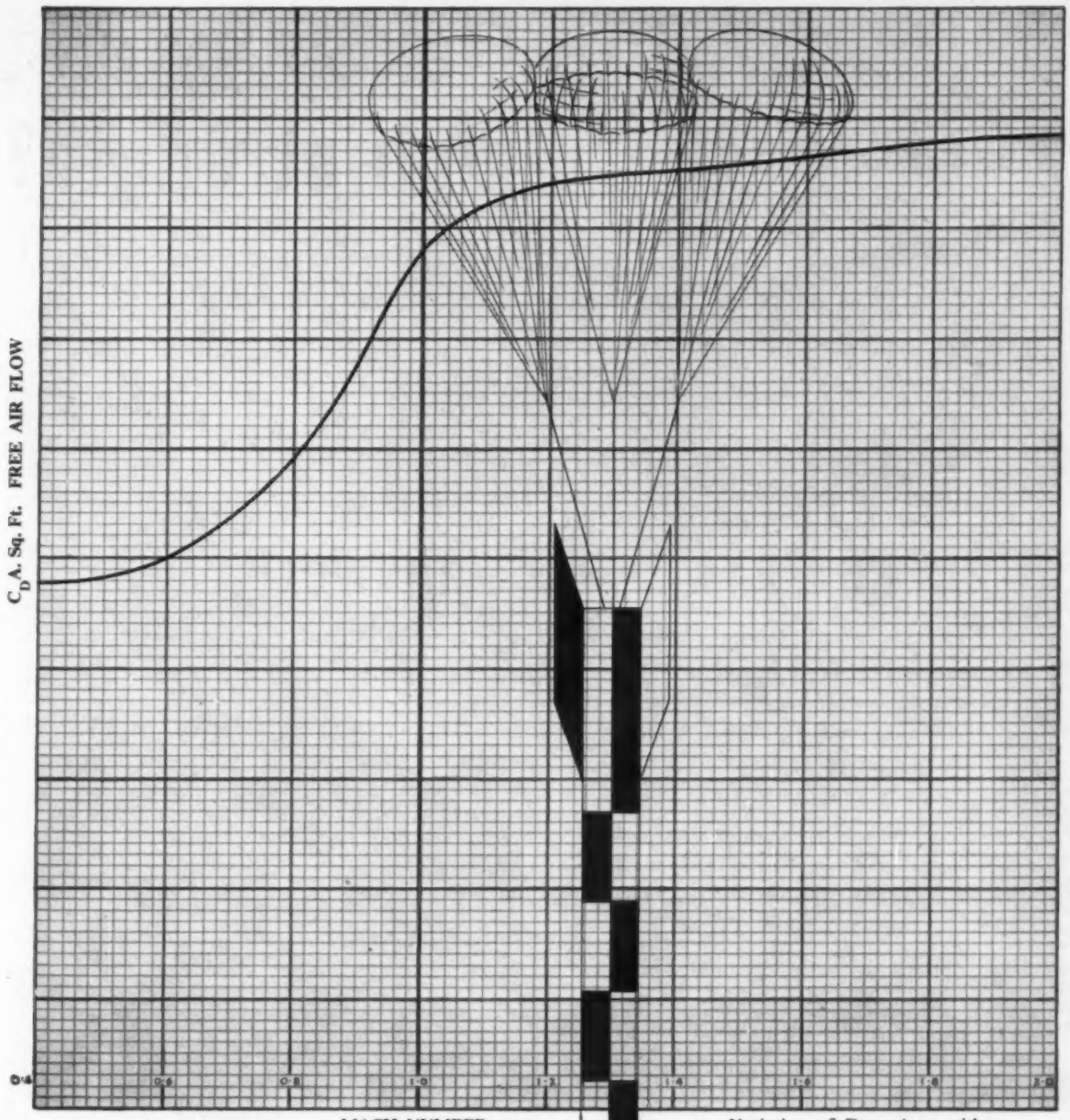
FALCON

United States Air Force (Air Defense Command and Far East Air Force); the missile is designated GAR-1, 2, 3 or 4.

Type: Air-to-air missile with semi-active radar or IR homing. Drawing: above (GAR-2A and GAR-3).

MANY thousands of Falcons have now been delivered from the Hughes Aircraft plant in Tucson, Ariz., and output is probably about one hundred per week. It is the most widely used air-to-air missile of Continental Air Defense Command, and is standard armament on all CADC interceptors (F-89H, J and K, F-101B, F-102A and F-106A and B).

History and description were published in our 1957 review. Production of the first two versions, GAR-1 (radar) and GAR-2 (infra-red homer) is complete. The later sub-types of both versions have several improvements, among which may be listed a refined airframe, a motor with higher total impulse, and control



Variation of Drag Area with Mach No.

Performance curve for G.Q. Supersonic Parachute.

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PAL 10

surfaces carried behind the trailing edge of the wing on outriggers. Both types of missile have blunt, rounded noses, one with a radome over the diminutive receiver dish and the other with a hemisphere of special glass covering the sensitive heat-seeker cell. GAR-1 and -2 are usually mixed in an intercepter load, and in most weather conditions it is common to fire one of each type in salvo to give the best chance of a kill.

Production is now concentrated on the much more potent GAR-3 and -4. Both incorporate the following major improvements: a longer Thiokol solid motor, giving higher specific impulse, greater thrust and longer burning time; a revised airframe with slightly lower supersonic drag; increased wing area and altered control surfaces for improved manœuvrability (especially at high altitude); and complete redesign of the guidance systems. As might be expected, GAR-3 is a semi-active radar homer, and it is matched to the new Hughes fire-control systems now in service, such as MG-10. The receiver dish is very similar to that of the later GAR-1s, but it is housed beneath a radically different pointed radome, made of a dielectric ceramic with a surface better able to withstand heat and abrasion. The GAR-4 is the corresponding IR-homer.

All these Falcons have high-explosive warheads. For at least two years it has appeared feasible to develop a Falcon with a nuclear warhead—an incredible achievement when one remembers the bulk of the atomic bombs dropped on Japan. The resulting weapon is GAR-9, and it is so different from earlier Falcons as to merit a new name (which it will probably get). It will be at least 20 per cent larger in linear dimensions, and probably more than three times as heavy. It will have very much greater range, but will retain a semi-active radar system.

Imminent flight testing of nuclear warhead Falcons was reported last March, and development is already far advanced. The first definitive contract for Hughes in respect of this weapon is expected to be for about $23m (not, of course, covering warheads), of which $3m was recently paid. The GAR-9 will be carried by the North American F-108A, and possibly by suitably modified F-106 and F-102 aircraft. Politically, it is already having to fight the Navy's Eagle (*q.v.*), but the Air Force are likely to ensure that GAR-9 will not come out of this conflict second-best.

GAR-1 and -2: length, 6ft 5.8in; body diameter, 6.5in; wing span, 20in; firing weight, 110 lb (GAR-1D) or 122 lb (GAR-2A); burn-out speed, over Mach 2; effective range, up to about 5 miles.

GAR-3 and -4: length, 7ft 1in; body diameter, 6.5in; wing span, approximately 29in; firing weight, approximately 150 lb; burn-out speed, probably at least Mach 3; maximum effective range, more than 5 miles.

FIREFLASH

Royal Air Force (No. 1 G.W.D.S.).

Type: Beam-riding, air-to-air missile. Drawing: p. 896.

FOR a considerable period Fireflash has been the only British guided weapon in full user service. Designed to ride a pencil radar beam emanating from the launching aircraft, Fireflash—which bears the code-name of Blue Sky—has no sustainer, but is boosted to supersonic speed by two jettisonable boost motors.

A detailed account of the missile was published in our issue of August 16, 1957. Fireflash has been used during the past 18 months as an indoctrination weapon to accustom the R.A.F. to the handling of air-to-air guided weapons. The unit involved is No. 1 Guided Weapon Development Squadron, and an account of a visit to their base at Valley, Anglesey, was contained in our issue of October 17 last. Each round fired by them—from Swift F.7s—transmits data along 24 channels, and statistical evaluation of weapon performance is at present being collated. Fireflash has proved itself extremely reliable and effective; but, as the chairman of the Fairey Aviation Company, who were responsible for its development and production, said in his recent annual report, "we must now look upon this project as being at an end."

Standard air-to-air missile for the fighter squadrons of the R.A.F. and R.N. will be the D.H. Propellers Firestreak. This round, seen under the wing of a Javelin of Fighter Command, has a conical plastic cover protecting its eight-faceted glass nose

Fireflash: length, 7ft 5in (9ft 3.75in with boosts); wing span, 28.1in; span of controls, 17.97in; overall height across boost fins, 23.63in; firing weight, approximately 300 lb; burn-out speed, over Mach 2.

FIRESTREAK

Royal Air Force (Fighter Command) and Royal Navy.

Type: IR-homing, air-to-air missile for launching from supersonic aircraft. Drawing: p. 896.

DEVELOPMENT of this fine weapon, which bears the code-name of Blue Jay, has been a major project by de Havilland Propellers, Ltd., since the end of 1951, and an extensive history was contained in our issue of May 3, 1957. Well over one hundred completely equipped rounds have been fired during development, and Firestreak has shown its ability to exceed in performance the operational requirements laid down for such a weapon.

Firestreak is quite a large weapon and has a circular-section body which tapers slightly ahead of the wings. The stubby wings form a fixed cruciform around the centre of gravity, and manœuvring is accomplished by a rear-mounted cruciform of small rectanguler control fins. An internal solid sustainer is fitted. In the nose is the sensitive heat-seeking cell, in the development of which Mullard played a considerable part. It is protected by a pointed nose, formed from eight facets of special glass, which offers maximum transparency to the transmitted infra-red radiation. The main power services inside Firestreak are pneumatic, the air being stored in a large toroidal bottle surrounding the motor blast tube.

In all installations so far revealed, the missile is carried externally, on a standard shoe attached to the aircraft pylon. From the aircraft are tapped supplies of hot and cold air to demist the glass nose of the Firestreak, keep the seeker cell at the correct temperature and cool the electronics. Three months ago a selection of airborne equipment, including the search radar, power supplies, fire-control boxes and heater pack, were publicly exhibited. All units required only for the Firestreak can be packaged in a quickly-demountable tray; and the R.A.A.F. Avon-Sabres used during development trials at Woomera carry the equipment externally in a belly fairing.

Last month it was officially stated that the D.H. weapon is designed for firing from anywhere within the hemisphere to the rear of a target, and, if fired from the bottom of this hemisphere, can be launched from a position 10,000ft beneath its quarry. The seeker cell is locked-on before the round is released. The prime contractor has succeeded in making Firestreak "practically impervious to IR radiation from natural sources . . . We believe that no other IR weapon has this degree of discrimination." On the same occasion it was stated that the warhead can destroy an aeroplane even from a large miss-distance and that a unique proximity fuze is employed.

Large numbers of rounds have been delivered to the R.A.F. and R.N. and, following the successful completion of acceptance trials, it should shortly be possible to release these to user squadrons. The principal carriers of Firestreak will be the Lightning, Javelin and Sea Vixen, the latter two aircraft carrying four rounds apiece. D.H. have inferred that the missile could, with development, be employed in the surface-to-air and air-to-surface rôles, and that more advanced versions of Firestreak are under development.

Firestreak Mk 1: length, 10ft 5.3in; body diameter, 8.67in; span of wings, 29.4in; span of controls, 19.1in; flight speed, clearly over Mach 2; maximum effective range, from 0.75 to 4 miles.

GENIE

United States Air Force (Air Defense Command) and, later, other formations, probably including NATO air forces.

Type: Unguided air-to-air missile with nuclear warhead. Drawing: p. 896.

ALTHOUGH unguided, Genie is a weapon of such importance that it would be undesirable to omit it from this review. Originally known as Ding Dong, Bird Dog or High Card (the training version, carrying a spotting charge only, was called Ting-a-ling), the production name for this missile is Genie and the designation MB-1. Prime contractor and airframe manufacturer is Douglas Aircraft.

The warhead is a miniaturized nuclear device with a sub-nominal yield (reported to be only 1.5 KT). This yield is large enough to destroy all aircraft within a radius of several hundred yards, and accordingly the only guidance necessary is spin-stabilization and correction against gravity-drop by four flick-out fins. Chief carriers of the Genie are the Northrop F-89J Scorpion, the McDonnell F-101B Voodoo and the Convair F-106 Delta Dagger. The F-89J carries the missile under wing racks, the F-101B mounts two on the underside of a rotating door and the 106 carries at least two rounds internally.

Pre-launch guidance is managed by the intercepter's Hughes MG-12 fire-control sys-

MISSILES 1958...

tem. At launching, about 1½ miles from the target, the missile is pointed slightly downwards, presumably to prevent the blast from the high-thrust Aerojet-General solid sustainer from damaging the aircraft or entering the intakes. An upward curving trajectory should then bring the Genie into the immediate neighbourhood of its quarry, detonation being effected by a proximity fuse by Panda Electronic Specialty Co.

A large number of Genies are now in service, the first issue to a squadron having been made in January 1958. The ground-handling and positioning trolley is by Fruehauf. It is clear that the present MB-1 is a relatively crude weapon, although an effective one. In February it was announced that a guided version, with greater thrust and longer range, was in advanced development. This version will also be produced by Douglas.

MB-1 Genie: overall length, about 8ft; diameter over warhead, about 15in; firing weight, probably about 1,000 lb; optimum range, approximately 1½ miles.

Perhaps the most lethal air-to-air missile in the western world is the nuclear-tipped MB-1 Genie. For more than a year this has been in squadron service with the U.S. Air Force; this one is carried by an F-89J and is illustrated with its stabilizing fins in the extended position

M.051

French Air Force.

Type: Radar guided air-to-air missile.

IN its essentials this missile is a version of the M.510, but guided by radar beam riding or semi-active homing. Its maximum speed is slightly lower, at Mach 1.5, and a small series has been completed.

R.510 (M.510)

French Air Force.

Type: Optical-homing air-to-air missile. Drawing: p. 896.

UNIQUE in that it employs a photocell seeker sensitive to electro-magnetic radiation within the spectrum of visible light, this relatively large missile is produced by the Soc. Matra and is in pre-production and limited service. It is carried by the Vautour and a development, the M.511, would have gone into service with the Trident. Full details were given in our 1957 review; propulsion is effected by a two-stage solid motor and the flight of the weapon is controlled by delta foreplanes and a ventral rudder in line with the delta wings on the rear part of the fuselage.

R.510: length, 10ft 5.9in; body diameter, 11in; wing span, 39.4in; firing weight, 353 lb; burn-out speed, Mach 1.7; maximum range, 8,750 yd in good visibility.

ROBOT 321A

Royal Swedish Air Force.

Type: Test vehicle. Drawing: p. 896.

THIS ground-launched vehicle is intended to be the initial stage in the development of an air-to-air missile, presumably to be carried by the J-32 Draken. The first 321A was launched on December 20, 1948, the instrument head being recovered by parachute. The basic missile has a cylindrical 7in-diameter body with a pointed ogival nose and a cruciform of delta wings. An internal sustainer is fitted, and boost propulsion is provided by a tandem motor with additional stabilizing fins. The size is noteworthy.

Robot 321A: overall length, 13ft (17ft 6in with booster); wing span, 36in (booster 39in); firing weight, 300 lb (630 lb with booster); flight speed, supersonic.

SIDEWINDER

United States Navy, Marine Corps and Air Force (Air Defense Command, Tactical Air Command and Far East Air Force), air forces of Australia, Western Germany, Norway and Japan and Royal Canadian Navy; the missile is designated AAM-N-7 (Navy) and GAR-8 (Air Force).

Type: Lightweight IR-homing air-to-air missile for firing from virtually any aircraft. Drawing: p. 896.

MORE wide usage than any other air-to-air guided missile in the Western world is the reward for the extreme simplicity, low cost and reliability of this pencil-slim weapon. Moreover, it has recently shown its effectiveness in actual operations, when—according to combat reports—14 Chinese Mig-17s were destroyed in a single October day by Sidewinders fired from F-86s of the Chinese Nationalist air force.

Prime contractors are Philco and G.E., original design having been done at NOTS, China Lake (see 1957 review issue for history). The missile is assembled from sections of light-alloy tube, comprising (front to rear): infra-red seeker head; guidance system, miniaturized servos, control ring and canard fins; distributed warheads, wrapped in optimum fragments; slender, 75in-long solid sustainer; and rear, fixed fins and motor nozzle. Airframes are produced by Hunter Douglas and Norris-Thermador, who have also made over a million Mighty Mouse spin-stabilized air-to-air rockets. In February it was reported that 13,000 Sidewinders had been ordered from the two primes, and that nearly all had been delivered. Follow-on orders were placed the following month, amounting to $15.5m for Philco and $9.5m for G.E.; these sums would buy a total of about 3,000 rounds.

Sidewinder: length, 9ft 5in; body diameter, 4.5in; fin span, approximately 19in; firing weight, 155 lb; burn-out speed, Mach 2.5; range, between 3,000 and 6,000 yd depending on visibility.

SPARROW

United States Navy and Marine Corps.

Type: Guided air-to-air missile for ship-board use.

THIS large and effective species of missile has been developed in three major versions, which, in view of the great dissimilarity, should be considered separately.

Sparrow I. A full history of this weapon was contained in our 1957 review. Developed for the Navy Bureau of Aeronautics by the Sperry Gyroscope Co., Sparrow I (AAM-N-2) was manufactured in quantity by the Sperry-Farragut Division of Sperry-Rand at the Naval Industrial Reserve Aircraft Plant at Bristol, Tennessee, between 1951 and 1957. Sparrow I is a beam-rider, with fixed tail fins and moving wings, all eight surfaces being of pointed delta form. It is in service with Atlantic and Pacific fleets, and can be fired by Chance Vought F7U-3M Cutlasses, McDonnell F3H-2M Demons and possibly other types of aircraft.

Sparrow II. This version was evolved by Douglas Aircraft in 1955 for the XF5D Skylancer; when the aircraft was terminated the missile programme was also cancelled. In 1956 the missile was selected as the standard air-to-air weapon of the Royal Canadian Air Force, and a consortium was formed to build it in Canada. This programme was cancelled three months ago. Sparrow II is a radar-guided weapon, with Bendix-Pacific guidance, and it has an airframe quite different from that of Sparrow I.

Sparrow III. In this missile a revised version of the airframe of Sparrow II has been matched with a completely new guidance system. Raytheon is the prime contractor, manufacturing the weapon at the same N.I.R.A. plant in Bristol formerly used by Sperry on Sparrow I. Compared with the earlier weapon, the III is slightly larger, and its aerodynamic surfaces are of considerably greater area; the wings are square-tipped and at least one of the fixed fins appears to fold in order to allow the missile to be carried partly submerged in a fighter fuselage. Raytheon also produce the semi-active radar homing guidance, the receiver for which is housed beneath an ogival nose radome about 22in long fabricated from heat-resistant ceramic material.

Propulsion is provided by an Aerojet-General sustainer with a single cast solid charge (not integral with the body). Future versions may be fitted with the Guardian pre-packaged liquid motor produced by the Reaction Motors division of Thiokol. Body and wings are mainly precision castings in aluminium alloy. The high-explosive warhead is larger than that of other American air-to-air weapons.

Flight testing is being conducted chiefly from the Naval Air Missile Test Center at Pt. Mugu, Cal. Raytheon have a Douglas F4D Skyray and a McDonnell F3H Demon on bailment from the Navy for this purpose. Operationally the carrier will be the Chance Vought F8U-3, which carries three rounds (one just off the centre-line, necessitating an offset nose undercarriage), and the McDonnell F4H, which mounts four (in pairs beneath the front and rear fuselage sections). The Sparrow IIIs are housed half submerged in both types of aircraft.

Sparrow I: overall length, 12ft; body diameter, 8in; firing weight, about 300 lb; burn-out speed, about Mach 2.5; range, up to 5 miles.

Sparrow III: overall length, approximately 12ft 6in; wing span, approximately 40in; body diameter, 9in; firing weight, approximately 370 lb; burn-out speed, probably close to Mach 3; effective range, at least 5 miles.

Correspondence

The Editor of "Flight" is not necessarily in agreement with the views expressed by correspondents in these columns. Names and addresses of writers, not for publication in detail, must in all cases accompany letters.

Beacon Identification

THE main cause of the fatal Winter Hill accident was that the radio compass had been tuned to the wrong station—MYL instead of MYK. The commissioner at the inquiry pointed out that recognition signals of beacons bearing the same initial, or initial two, letters, might contribute to errors of identification.

In *Flight* for December 30, 1955, we read: "The use of three-letter call-signs for radio facilities offers over 15,000 alternatives; it should be simple to allocate call-signs so that nearby beacons cannot be confused."

It is unfortunate that an accident should have to happen before anything was done about the present system of tidily assigning similar call-signs to one area. Let us hope that prompt action will be taken here and abroad to end this needless risk of confusion.

Maidenhead, Berks. H. L. LEE.

Comet and 707 Noise

WHATEVER the "Decibel Boffins" may say on the subject, I submit, after witnessing the take-off of both the 707 and the Comet aircraft, that the noise levels are in no way comparable.

The Comet take-off struck me as being almost disappointingly ordinary and the noise it made was much less than that of a Super-Connie. The 707, on the other hand, resembles some monster from another planet rather than an aircraft; not only is the noise deafening, but the dense plumes of smoke emitted must, when added to the smog and haze of London, create a serious problem for other aircraft waiting to take off.

Ickenham, Middlesex. H. T. F. GREEN.

Jet-airliner Pilots' Pay

HAVE you sir, as Editor, ever considered syndicating Roger Bacon's column? There are many magazines in the world with an aviation interest, and if it were syndicated "Straight and Level" might be enjoyed by far more readers, perhaps 30 times as many.

My reason for asking this question is that I wonder what Roger Bacon's reaction would be if you were able to sell his column elsewhere. Would he be satisfied with his present salary, or would he ask for a rise? He wouldn't be working any harder, but there is every precedent for a writer being paid in proportion to the number of his readers.

It is quite fair to extend this argument to the case of pilots. A 707 is said to have a productivity equivalent to that of 30 Dakotas. Even in the unlikely event of the pilot working no harder, he has a greater responsibility, and is exposed to a greater nervous strain. He wouldn't expect to get 30 times the salary, but a rise would obviously be justified.

Roger Bacon says he is very worried about the justification for pilots' differential pay; if he is as straight and level as he claims he will doubtless accept the validity of this argument.

London Airport. NEIL COLLEN.

Not Only Croydon

MOST of us who work for a livelihood in British civil aviation will have nothing but sympathy for the Croydon Airport operational tenants. However, their troubles are not isolated. Here in the North, Liverpool and Blackpool Aerodromes are threatened with early closure or take-over by local authorities. The latter aerodrome has been famous in aviation since the first of its flying meetings in 1909.

Over the past twelve years at Blackpool, eight concerns have gone out of the aviation business and each year the aerodrome becomes more of a general trading estate. With the restrictions now wittingly or unwittingly imposed by the Ministry it is not possible to achieve anything like an economic utilization from our aircraft. We have, therefore, to look away from Blackpool to effect a sensible usage.

We, the "oldest inhabitants," have supported Squires Gate Aerodrome since the M.C.A.'s first year. If we had invested part of our gratuities in a crystal ball I would have no hesitation in saying that the thousands of pounds we have largely wasted on accommodation charges would have been put towards a privately controlled flying field.

A lot of the Ministry boys lack practical experience and rely too much on "the book." They also lack that (as far as the M.T.C.A. are concerned) uncommon quality called common-sense. Once upon a time we had here a senior official who seldom had to use his "book." Movements increased, life was brighter. He exercised both experience and common-sense and was like a breath of fresh air in a stuffy room; but the windows were soon closed again—he was quickly posted.

The time is ripe for Mr. Harold Watkinson to recruit a representative committee of operators and M.T.C.A. experts to get together in friendly fashion to discuss and encourage energetic action over the many and varied problems which face both the Ministry and the operators.

I think that such team-work, wholeheartedly given on both sides, would achieve better results than the formation of a M.T.C.A. tenants' association. The formation of such an association could result in more battle than progress.

Squires Gate, Blackpool. RUSSELL C. WHYHAM,
Air Navigation and Trading Co., Ltd.

Flying-hour Records

I WAS interested in the various comments you have received on the flying time accumulated by some pilots. As an airline we feel that our captains have higher average hours than any other international carrier.

Our chief pilot, H. C. Gilmore, has alone amassed 20,200 hours' logged time. Another senior captain, Ralph Johnson, has in fact logged over 30,000 hours. Capt. Johnson had retired from United Air Lines and has continued his exceptional career of flying with Air Jordan. As a matter of interest he holds a United States C.A.A. licence in the 200 series, which surely makes him one of the most active of an original breed.

Amman, Jordan. WALTER B. MCCARTHY,
Director of Traffic and Sales, Air Jordan.

Unfair to Space Hero?

I NOTED with interest Mr. R. Randal Phillips's very fine précis (*Flight*, October 31) of Jules Verne's classic, *From the Earth to the Moon*. As a lad, I read the book and was particularly impressed by the plausibility of Verne's mathematical approach. Only a few years ago I re-read it to savour again its delightful treatment of a subject now so prominent. And I did want to check on a question which had vaguely puzzled me for years. That is, how did Barbicane and company get going so fast in so short a distance? I found out.

Here is the answer, using high-school physics and the figures which appear in Mr. Phillips's article. The shell attained the velocity of 12,000 yd/sec in 900ft of distance. Assuming constant acceleration,

$$a = \frac{V^2}{2S}$$
$$= \frac{(3 \times 12{,}000)^2}{2 \times 900}$$
$$= 720{,}000 \text{ft/sec}^2$$
$$= 22{,}200\ g$$

Where a = Acceleration in ft/sec²
V = Velocity in ft/sec
S = Distance in feet

This is enough acceleration to cause an upright S.A.E. 1025 steel bar or tube less than 6in long to crumple from its own weight.

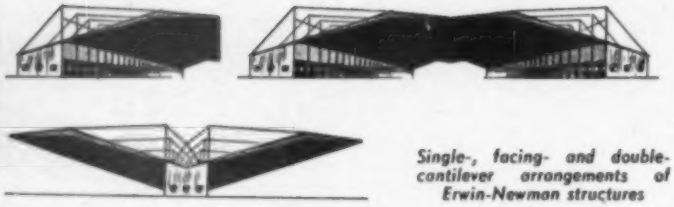
Old Jules was smart enough to avoid subjecting his hero to this kind of treatment—literally, that is. In the U.S. vernacular, Barbicane couldn't even have taken it lying down.

Arlington, Va., U.S.A. HAROLD HOEKSTRA.

FORTHCOMING EVENTS

Dec. 5. Helicopter Association: Film Show
Dec. 6. British Interplanetary Society: "Rocket Nozzles and Jets," by E. T. B. Smith.
Dec. 8. Royal Society of Arts: Cantor Lecture (3), "The Future of the Aeroplane," by Eric Mensforth.
Dec. 9. R.Ae.S.: "Application of a Constant Frequency, A.C. Electrical System to Aircraft and Missiles," by S. S. Hall and A. Thomas.
Dec. 9. R.Ae.S. Graduates' and Students' Section: "The Future of the British Aircraft Industry," by E. C. Bowyer.
Dec. 10. British Institution of Radio Engineers (North Eastern Section): "High Resolution Airfield Control and Ground Surveillance Radar," by P. H. Walker.
Dec. 10. Kronfeld Club: "Cambridge University Gliding Club," by Ken King.
Dec. 10. Royal United Service Institution: "With the Army and Royal Air Force in the Middle and Far East," by William Courtenay.
Dec. 15. R.Ae.S.: Discussion on Hypersonic Flow.

R.Ae.S Branch Fixtures (to Dec. 12): Dec. 9, *Boscombe Down*, "Beating the Heat Barrier," by J. Taylor; *Bristol* (Junior Committee), "Nuclear Propulsion," by Prof. A. D. Baxter; *Glasgow* (Graduates' and Students' Section), "Training the Aeronautical Engineer," by A. W. Babister. Dec. 10, *Brough*, "Procedure of Test Flying at Supersonic Speeds," by W/C. R. P. Beamont; *Chester*, "Interplanetary Instrumentation," by B. P. Clear; *Christchurch*, "Electronic Control of Machine Tools," by H. Ogden; *Coventry*, junior lectures and films; *Gloucester*, "Development of High-Performance Sailplanes," by D. H. G. Ince; *Manchester*, "Civil Aircraft Production," by P. Imlach; *Preston*, "Emergency Stopping of Aircraft with Over-run Runways," by Dr. J. Thomlinson; *Reading*, "Servicing of Civil Aircraft," by J. Gregory; *Southampton*, "Aircraft Accident Investigation," by G. W. Acock; *Swindon*, "Any Questions?"; *Weybridge*, R. K. Pierson Memorial Lecture, by B. S. Shenstone. Dec. 11, *Isle of Wight*, a.g.m. and film show. Dec. 12, *Belfast*, annual dance.



Single-, facing- and double-cantilever arrangements of Erwin-Newman structures

Suspended-cantilever Hangars

A TYPE of hangar popular in America, where several hundred are in civil and Service use, is now being constructed under licence in this country. It is the Erwin-Newman hangar, the roof of which is a cantilever girder structure that requires no support columns along the frontage or even at the two ends. Three sides can thus be opened for unobstructed movement of aircraft or vehicles.

The roof is cantilevered from a series of vertical members at the rear, and these are in turn stayed by 45-deg members from a ground structure. The space between the verticals and the stays can be filled by workshop accommodation of almost any design, single storey or multi-storey.

Some remarkable clear-span widths are possible. Temco Aircraft Corporation, for example, had an Erwin-Newman hangar of 30ft door height and 432ft span, and the span was subsequently increased by the addition of standard sections to give 576ft, still without vertical supports. Low cost of erection is also emphasized; a hangar of 32,000 sq ft area, it is stated, was recently built in six working days.

Various arrangements of sheet-metal or masonry walling can be used, and doors (or gates to accommodate tail fins) can be installed at any point.

The licensees are the Anglo-American Hangar Co. (one of the James Dootson group of companies), 436 Grand Buildings, Trafalgar Square, London, W.C.2. They can undertake complete erection or, alternatively, can supply plans for contractors, the design fee in this case including a licence to erect the structure under the British patents.

Avro Missile Posts

TWO new appointments to the A. V. Roe and Co., Ltd., weapons research division—currently concerned with production and development of the stand-off bomb—have recently been announced. Mr. A. Sewart has been made assistant general manager (missiles), in this post being directly responsible to Mr. J. A. R. Kay, the general manager; and Mr. R. W. Ward becomes chief development engineer of the weapons research division, with direct responsibility to its chief engineer, Mr. R. H. Francis.

Mr. Sewart joined A. V. Roe in 1925 as an apprentice. In the post of experimental manager (1945-49) he was responsible for the prototype building of the Tudor, Shackleton, Athena, Ashton and Avro 707; and more recently he has been production controller (with responsibility for all pre-production planning) and works manager.

Mr. Ward, who took up his new appointment on December 1, has joined A. V. Roe from Gloster Aircraft. He had been chief experimental designer there since 1953 (having been with the company since 1935) and was closely concerned with the design of the E. 28/39, the Meteor and the Javelin.

Philips colour-corrected 400W mercury fluorescent lamps with internal reflectors are employed for lighting the new twin-cell test bed installed by B.O.A.C. at their Treforest, South Wales, maintenance base. Philips Electrical, Ltd., state that the level of illumination achieved by these lamps—35 lumens/sq ft—is approximately three times that obtained with conventional mercury fluorescent lamps mounted in similar fittings

THE INDUSTRY

Advice from the C.A.S.

WHEN the Chief of the Air Staff, Marshal of the Royal Air Force Sir Dermot Boyle, presented prizes to Handley Page apprentices on November 21 he spoke of the long association between the company and the R.A.F. and recalled that at no time had the latter been without Handley Page aircraft in service. He went on to emphasize that scientists must broaden their outlook and be awake to what was taking place outside their own sphere; they must realize that men who rose to great positions were those who continually asked questions.

In his review of the year's work by the company's apprentices, Sir Frederick Handley Page said that there had been a continuation of the trend towards the sandwich course, students spending six months in study and the remainder of the year gaining practical experience in the company's works and offices. Apprentices studying for university degrees and diplomas had increased in number.

Dr. J. S. Tait, principal of Northampton College of Advanced Technology, announced the formation of an aeronautical department which would give extended facilities to apprentices studying at the college.

Among awards announced were those of an S.B.A.C. scholarship to John Radcliffe; a Handley Page major to Nigel B. Carruthers; and a NATO scholarship to Peter Simpkins.

Solartron Progress

SPEAKING at the general meeting of the Solartron Electronic Group, Ltd., the chairman, Mr. John E. Bolton, D.S.C., M.A. (Cantab.), M.B.A. (Harvard), reviewed the company's increasingly wide field of activity. This includes the manufacture of a range of basic radar simulators which, said Mr. Bolton, was now being extended to include seaborne and airborne installations; in the past nine months the group had submitted quotations and estimates to the value of more than £1m to various NATO and SEATO countries. New developments in data-processing included unbonded strain-gauge pressure transducers for the nuclear power, aircraft and missile industries, and analogue magnetic tape recording equipment—under licence from Consolidated Electrodynamics Corporation—for the same fields of industry.

In his financial review, the chairman said that trading profit, before taxation, had increased by some 80 per cent and net profit by almost 200 per cent over the previous year's figures.

IN BRIEF

Auto Diesels, Ltd., have received a £72,000 contract for ground starting equipment for Aerolineas Argentinas' new Comet 4 fleet.

* * *

Mr. T. F. Minter, formerly manager of technical services at the Goodyear headquarters at Akron, Ohio, has been appointed manager of the Garscadden, Glasgow, plant of the Goodyear Tyre and Rubber Co. (Great Britain), Ltd.

* * *

Mr. John Page has joined the staff of Dr. Allan C. Waine, research director of the Triplex Safety Glass Co., Ltd., at the firm's principal factory at King's Norton, Birmingham. He will assist Dr. A. J. Holland, the chief physicist, on all projects connected with safety glass for the aircraft industry.

* * *

Racal Engineering, Ltd., has formed a new instrument division with its own development laboratories under the chief engineer, Mr. N. Elson, M.A., M.Sc., A.M.I.E.E. It also includes a special products section which will design, manufacture and install digital or non-digital instrumentation schemes for special applications. Sales manager of the new division is Mr. I. H. M. Campbell.

* * *

Queen Juliana of the Netherlands has conferred upon Mr. E. G. Parramore the Knighthood of the Order of Orange-Nassau "in recognition of his distinguished services to the Netherlands aircraft industry." Mr. Parramore is the Plessey International representative in Amsterdam; before joining Plessey in 1956 he was for three years director of the Hawker Hunter production office at The Hague and also acted as technical adviser to the Royal Netherlands Air Force.

* * *

Mr. Eric Walker has been appointed managing director of the Phosphor Bronze Co., Ltd., in succession to Mr. A. N. Wormleighton. Mr. Walker has been associated with the Birfield Group since 1948, first as works director and then sales director of Kent Alloys, Ltd., and for the past year he has been director of Birfield's aviation and engineering division. He will be assisted by Mr. Philip A. Broadbent, A.M.I.Mech.E., A.M.B.I.M., Mr. Jack Kitchen and Mr. Gordon Swinyard, M.Sc., A.I.M.

SAS chose the 'Air Partner'

Scandinavian Airlines System will use 10 Atlas Copco 'Air Partner' compressors to service their fleet of DC-8 jet airliners

STARTING · AIR CONDITIONING · DE-ICING

The Air Partner is a surge-free rotary screw compressor of the Lysholm type designed for starting, air conditioning and de-icing all jet and turbo-prop airliners having air turbine starters.

A SUCCESSFUL COMBINATION

Atlas Copco, the world's largest organisation devoted exclusively to the manufacture of compressed air equipment, combined aeronautical expertise with compressor know-how to produce this multi-purpose unit.

STARTING

The Air Partner delivers a continuous flow of warm, oil-free air to turn the engine over constantly thus eliminating mis-starts.

AIR CONDITIONING

The Air Partner becomes an air conditioning unit by merely flicking the appropriate switches and pressing a button, a matter of seconds.

DE-ICING

A special mouthpiece attached to the air hose enables the wings and fuselage to be 'sprayed' with warm air. Removal of ice and sleet from windshields, wing leading edges, and air intake lips is achieved by using the ordinary de-icing outlets of the aircraft.

SIMPLE MAINTENANCE

The Air Partner has no wearing parts. It consists of two screw rotors which intermesh but never touch one another or the casing. 10,000 hours is the normal period between overalls for screw compressors of this type.

Maintenance operations can be carried out by airline personnel anywhere in the world or through the Atlas Copco sales and service organisation established in 90 countries.

TWO MODELS

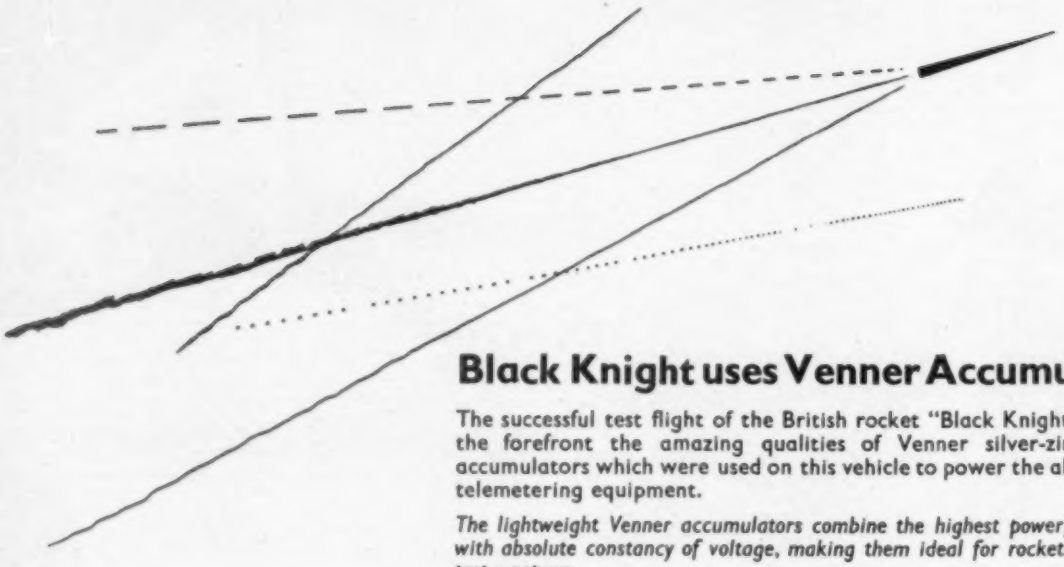
Air Partner M-3 consists of two identical units, each including a compressor connected to a standard petrol or diesel engine, for starting, air conditioning, de-icing and checking auxiliary systems.

Air partner M-2 consists of one rotary screw compressor connected to a standard petrol or diesel engine for starting and limited air conditioning.

THE *Atlas Copco* AIR PARTNER

A contribution to the jet age of air travel

Contact your local Atlas Copco company or agent or write to Atlas Copco AB, Stockholm 1, Sweden



Black Knight uses Venner Accumulators

The successful test flight of the British rocket "Black Knight" brings to the forefront the amazing qualities of Venner silver-zinc reaction accumulators which were used on this vehicle to power the all-important telemetering equipment.

The lightweight Venner accumulators combine the highest power/weight ratio with absolute constancy of voltage, making them ideal for rockets and guided test weapons.

For further details write to Dept. F.

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Polish Aircraft and Helicopters

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POLSKIE ZAKŁADY LOTNICZE

PZL-102 KOS. Modern, light, two-seat, all-metal low wing monoplane for sports and travel, with 65 h.p. engine.

PZL-101. Agricultural aircraft, for dusting and spraying. Container—capacity 500 kg.

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BIES TS-8. School and training aircraft.
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Even pilots like to breathe

For a time it looked as though they might have to give it up. Because space and weight restrictions made it more and more difficult to squeeze vast supplies of oxygen into aircraft which were forever flying higher and higher.
But British Oxygen for a long time had been selling liquid oxygen to their customers. Liquid oxygen is 861 times denser than gaseous oxygen and is stored at one tenth of the pressure so the equipment for its use is lighter and smaller. Just the thing to keep aircraft designers happy!
So B.O.A.E. designed a liquid oxygen automatic supply system consisting of a converter, three valves, piping and electronic contents gauging, which provided gaseous oxygen for breathing purposes. It is now being supplied for the English Electric Lightning, De Havilland Sea Vixen, Vickers Supermarine Scimitar, Fairey Gannet, Folland Gnat Trainer and other advanced aircraft.
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Aro
Equipment

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British Oxygen Aro Equipment combines the resources of the British Oxygen group of companies and the Aro Equipment Corporation of Ohio

HIGH OUTPUT
FUEL FILTERS

Fig. 1

A new Stream-Line development to extend their range of aircraft refuelling filters

Stream-Line filters (types K and PM) are well known for high efficiency and absolute reliability for the removal of solids and traces of finely dispersed water at the point of actual fuelling into aircraft.

To meet the demand for a filter of much greater capacity in applications where removal of solids only is required, a new filter element has been designed using a specially developed impregnated paper in deeply pleated form through which the fuel is passed actually between the individual *fibres* of the paper (Fig. 1) instead of between consecutive papers as in the standard K and PM 'edge' type elements (Fig. 2). *Our engineers will be pleased to discuss this filter with you.*

Fig. 2

* The 400 G.P.M. filter is only 20" diameter & only 32" long. The 1,000 G.P.M. filter is only 36¼" diameter & only 40 long.

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STREAM-LINE FILTERS LTD · INGATE PLACE · LONDON · S.W.8
A Member of the VOKES Group Telephone: Macaulay 1011
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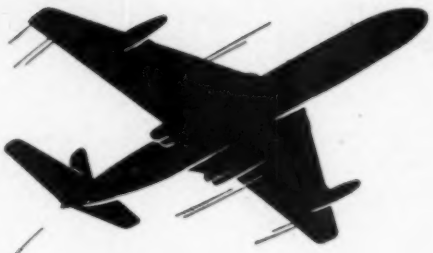

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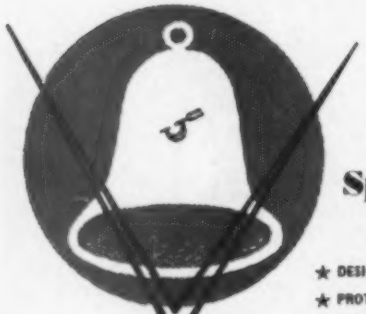

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The manufacture of blade form gauges for some of the world's leading aero-engine manufacturers have given us the opportunity to work to such limits, in conjunction with surface finishes of one micro inch.

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What aircraft is this?*

Whatever the aircraft you can be sure it's fitted with

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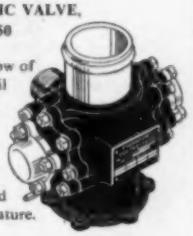

Modulates the flow of oil through the oil cooler so that when the oil temperature exceeds 50°C the flow through the cooler is increased to reduce temperature.

* *See page 56 for answer.*

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REGD. TRADE MARK

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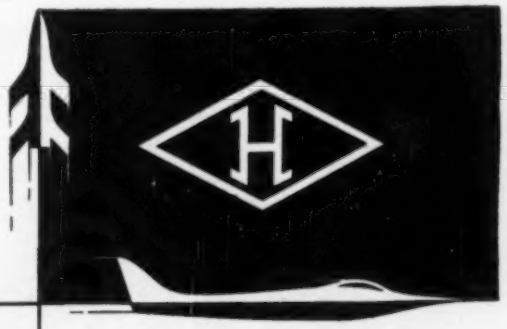
"DIAMOND H" 4 Pole Double Throw Hermetically sealed miniature RELAYS for Guided Missile & Aircraft applications

High Performance

Greater Reliability



BRITISH RELAYS NOW AVAILABLE

RATING:-
10 amp. 30 volt D.C. 115 volt A.C.

TEMPERATURE RANGE:-
55°C to 200°C

SHOCK RESISTANCE:-
50 G

VIBRATION RESISTANCE:-
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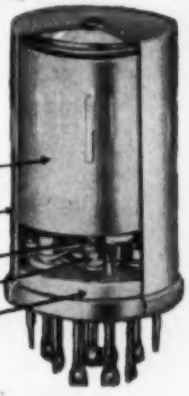
NEW! SERIES S RELAYS—

The special version of the series R for dry circuit reliability
Separately sealed coil.
Inorganic switch.



'DIAMOND H' SWITCHES LTD., GUNNERSBURY AVENUE, CHISWICK, W.4.

TELEGRAMS: DIAMONHART CHISK LONDON

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Designers and manufacturers of the ground handling equipment for the

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We are also manufacturers and designers of missile cooling units—cooling trolleys specially designed to prevent overheating of missile equipment prior to launching.

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Telephone LEYTONSTONE 5464

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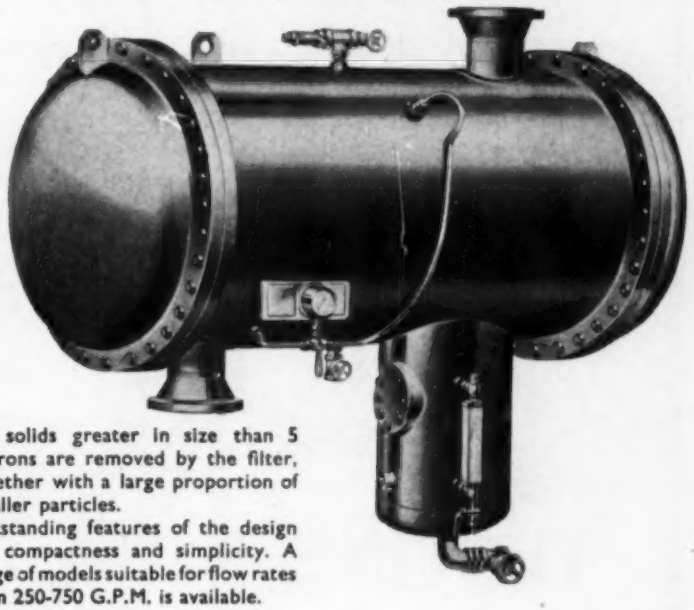
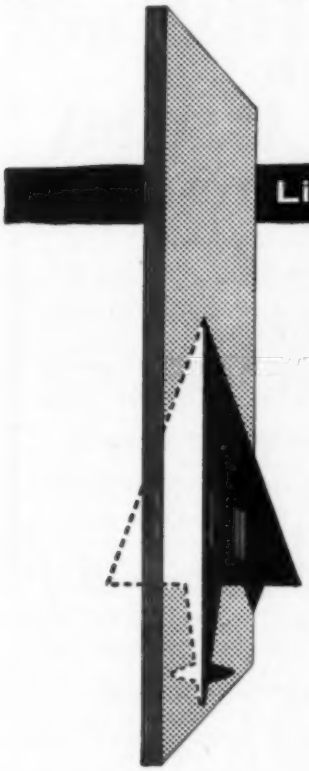
FOR CLEAN FUEL *free from dirt & water*



The Purolator fuel filter-separator is primarily intended for use at aircraft refuelling installations. This unit, which is very compact, performs two important functions at the same time; it not only extracts water from the fuel but also arrests solid particles without the use of an additional filter.
The efficiency of water removal depends to some extent on the operating conditions, but Purolator filter-separators have proved at least 99·98% efficient in most circumstances.

All solids greater in size than 5 microns are removed by the filter, together with a large proportion of smaller particles.
Outstanding features of the design are compactness and simplicity. A range of models suitable for flow rates from 250-750 G.P.M. is available.

PUROLATOR FILTER-SEPARATOR
Regd. Trade Mark: Purolator
AUTOMOTIVE PRODUCTS COMPANY LIMITED, LEAMINGTON SPA, WARWICKSHIRE, ENGLAND



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Most people concerned with metals know what it is but not everyone is aware of what it can do. If you feel that you should know more about this light, strong and corrosion-resistant metal, then write for brochure on properties and forms to:

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2 METAL EXCHANGE BUILDINGS
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"ROLLERS OF MODERN METALS"

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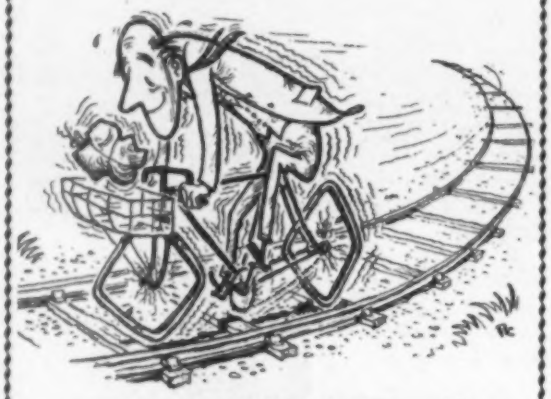

TESTING ?

Today's rapid increase in the speeds of Guided Missiles, Aircraft and various types of machinery has made the Engineer acutely aware of vibration.

Full scale testing is often expensive, though ultimately necessary, yet it is possible to assimilate the conditions under which parts will work by inducing controlled vibration and modifications can then be made at the design stage. In this field, W. Bryan Savage Ltd. have been actively engaged for the past twenty years and are one of the leaders in the manufacture of Power Amplifiers and Vibrators.

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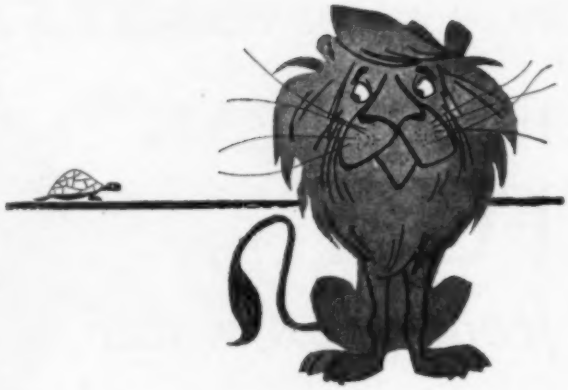

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★ Give precision results with unskilled labour
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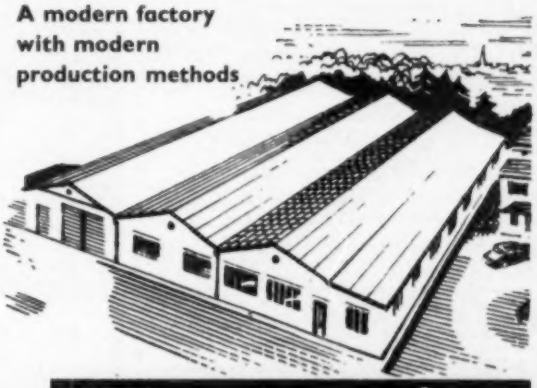

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VICKERS VIKING. Long nosed aircraft, excellent condition. Full air line standards. £23,000 each.
DOVES. Several available from £11,500.

THE above transport aircraft for sale through our offices represent the best values on the world market today. Full details sent on request.

And for the Private and Business Pilot

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AUSTER J.4 Engine hours since overhaul, 200 (800 hour life). Excellent condition. C. of A. till August 1959. £850.
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CHIPMUNK. Another of these delightful aircraft, at a most attractive price.
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IT'S IN OUR INTEREST TO TAKE CARE OF YOUR INTEREST and Shackleton's have the experience to do just that

WE welcome your inquiries with no obligation whatsoever.

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What can be more ideally suited to our winter weather than a

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What aircraft...?

The puzzle picture in the Teddington Aircraft Controls Ltd. advertisement on page 51 shows part of the Sea Vixen.

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December 19, 1958, issue will close for Press first post Wednesday, December 10, 1958.

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FLEET of four D.H. Dove aircraft Gipsy 70/4 engines, together with comprehensive spare holding. Hire purchase terms arranged. Further details apply Channel Airways, Southend Airport, Essex. [0031
AVRO XIX, excellent condition throughout, economical executive aircraft. Cheetah 17 engines, V.P. fully feather propellers. Airframe only 1,100 hours since new. Dual control, 7 passenger seats, long range tank fitted, 2 extra seats available. STR 12 A 50 channel VHF Bendix Radio Compass, Fan Marker. C. of A. valid until July 1959, £4,000 or best offer. G. Farley, Lec Refrigeration, Ltd., Bognor Regis. [8507

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DUAL control set, for Messenger. Box No. 0325. [0610
ROLLASONS are specialists in the overhaul of all Gipsy engines. CROydon 5151. [0133
H. T. NEWTON AND CO. AND NEWTONAIR LIMITED, Gatwick Airport, for all your aircraft electrical and electronic requirements, A.I.D. and A.R.B. [0299
GIPSY MAJOR Mk 10 and Mk 1 engines. Part exchange offered with time-expired engines. Propellers for most types light aircraft. Mitchell Aircraft, Ltd., The Airport, Portsmouth Tel.: 717641. [0351
VENDAIR, Croydon Airport, offer Gipsy Major, Queen 2, Queen 30, Queen 70, Lycoming, Cirrus, engine spares.—Apply Vendair, Croydon Airport, Croydon. Tel.: CRO. 5777. [0601
PHILLIPS AND WHITE, LTD., offer from stock instruments and instrument parts. Navigational equipment, electrical components, airframe parts and hydraulic components and parts. Engine spares for de Havilland Gipsy Major and Queen series, also Armstrong Siddeley Cheetah IX, X and VX spares. 61 Queen's Gardens, London, W.2. Tel.: Ambassador 8551, 2764. Cables: Gyrair, London. [0466

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APPLICATION No. 2362 between Blackpool and London.

APPLICATION No. 2363 on the route Blackpool - Southport - Isle of Man.

FROM East Anglian Flying Services, Ltd., of Southend Airport, Essex:—

APPLICATION No. 546/3 for an increase in frequency from 10 to 20 return flights weekly on the U.K. Internal Service which they are at present authorised to operate from June to September each year with D.H. Dove and D.H.89 aircraft on the route Portsmouth - Guernsey (opt.) - Jersey until 31st March, 1960.

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FROM Starways, Ltd., of Liverpool Airport, Liverpool 24, for the following normal scheduled services with Dakota and DC-4 aircraft for the carriage of passengers only at an initial frequency of 12 return flights weekly on each service increasing later in accordance with traffic demand for seven years from 1st April, 1959:—

APPLICATION No. 2368 on the route Glasgow - London - Ostend.

APPLICATION No. 2369 on the route Liverpool - London - Ostend.

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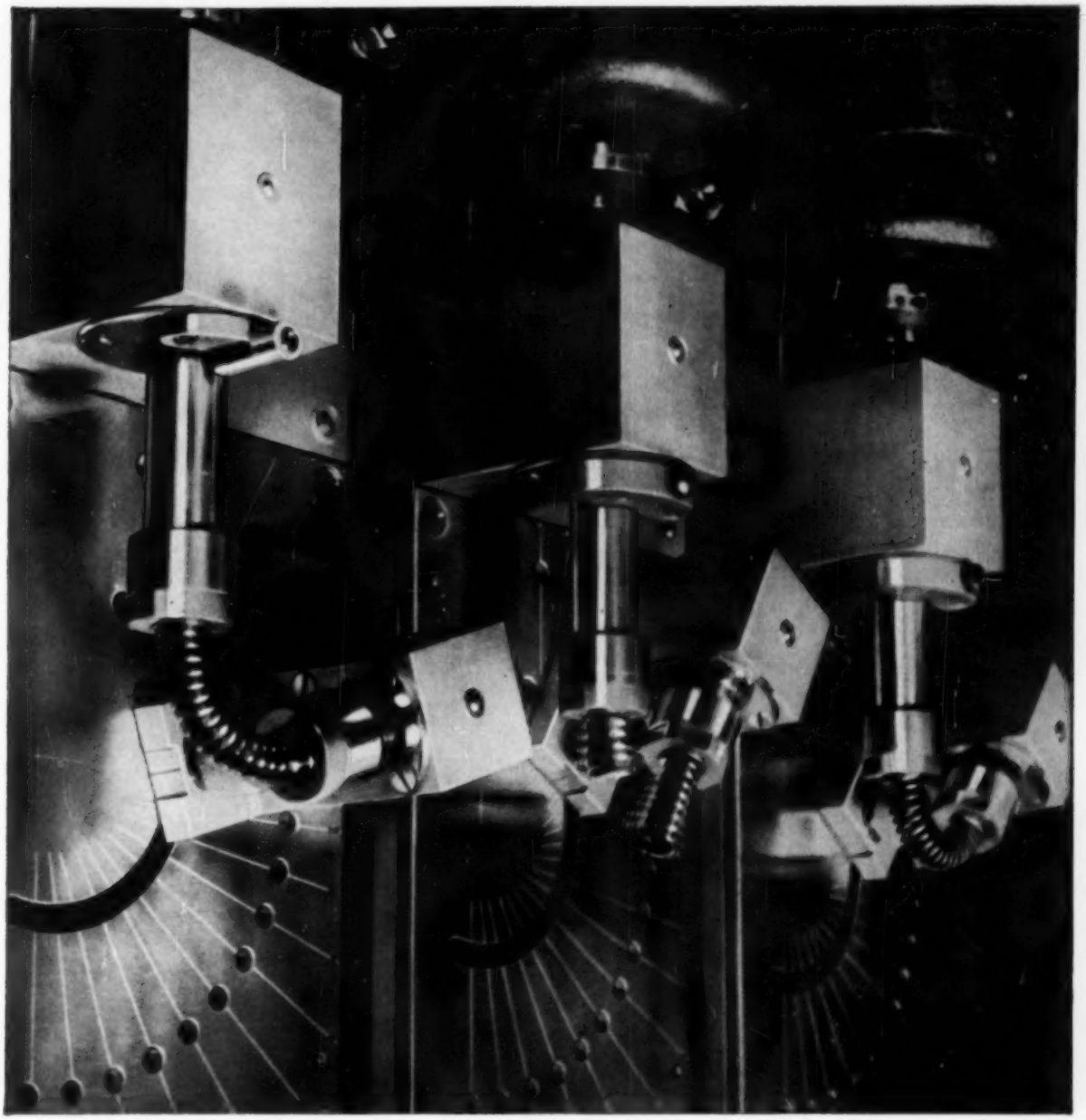

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This ensures highest accuracy—regardless of range. Missiles may be fired singly or in salvoes using only one radar.

Airframe. Employs unique and advanced monoplane moving wing configuration—two advantages: quicker and more precise response, as well as greater accuracy of interception—superior at high altitudes; this configuration was selected at initial design stage to embody maximum development potential.

BRISTOL/FERRANTI

Bloodhound

GUIDED WEAPON SYSTEM

Weapon design and construction by Bristol. Guidance and control by Ferranti. System sales organisation by Bristol Aircraft Limited